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RESULTS IN 278 PATIENTS WHO HAD THE MODERN TYPE OF THORACOPLASTY FOR TUBERCULOSIS

FOLLOW-UP OF LIVING PATIENTS FIVE TO FIFTEEN YEARS AFTER OPERATION

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THE scarcity of information about the long-term results obtained from thoracoplasty in pulmonary tuberculosis prompted us to undertake this study.[1] Reports from different clinics have appeared recently with increasing frequency, but few, if any, are based upon follow-up examinations made five years or more after the performance of the so-called modern type of thoracoplasty (as described by Alexander[2]).

Because of the great difficulties that would be encountered in following patients after their return to many different sanatoria, it was decided to study only those patients who had been referred to the University Hospital by the Michigan State Sanatorium, at Howell, Mich., and to which almost all of them returned for their convalescence.

The use of patients only from the Michigan State Sanatorium permitted us to study a relatively large group of persons who were followed actively by the Outpatient Department and all of whom had cultures made of sputum or gastric contents. All the patients were transferred to the University Hospital for operation and all the thoracoplasties were performed between Jan. 1, 1935, and Jan. 1, 1945. January, 1935, was chosen as the beginning date for this study as the modern type of thoracoplasty had become routine by that time; January, 1945, was selected as the terminal date as a minimum five-year follow-up could thereby be secured, since the study was completed at the end of 1949.

Three hundred seventeen patients from the Michigan State Sanatorium had a total of 1,388 stages of thoracoplasty performed by various members of the thoracic surgery staff of the University Hospital. All patients who were

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not known to be dead were sent questionnaires in order to establish contact with them. Most of the patients returned to the sanatorium for a check-up examination. Some did not return due to the long travel time required by the location of their homes, or were unwilling to come. For this group, we arranged to have a roentgenogram made near their homes and sent to us. Also, one or more sputum specimens were collected and sent either to the Michigan State Sanatorium or to a near-by state laboratory for culture, and the reports were then sent to us. If any patient had had a positive sputum culture at any time after discharge from the sanatorium, three specimens were required from him before he was considered negative.

Thirty-nine patients did not answer the questionnaire, and no information about them could be obtained through local health authorities, local chapters of the National Tuberculosis Association, or the police. Since follow-up data of more than five years were not available about them, they have been excluded from the study, leaving 278 patients for analysis. We feel that this is reasonable, since a study of the case records strongly suggests that the majority of these thirty-nine patients were progressing favorably. Thirteen patients of this group were followed for less than one year after operation, and only one remained positive (three had negative cultures, and nine had negative concentrates) thirteen were followed for one to two years (one remained positive, two had negative cultures, and ten had negative concentrates); ten were followed two to three years (one remained positive, six had negative cultures, and three had negative concentrates); three were followed for three to five years (three had negative concentrates); the patients mentioned above as having negative concentrates had no cultures made since the study of their sputa was prior to 1940 when routine cultures were begun. A number of them were migrant Mexicans and Indians, and eight others had moved to other states. Therefore, to list the thirty-nine as dead would, we feel, give a falsely unfavorable impression of the value of thoracoplasty. Nineteen other patients failed to answer the questionnaire, but are included in this study because we had adequate data about them five years or more after operation.

Of the 278 patients in this study there were 145 men (52.2 per cent) and 134 women (47.8 per cent). The youngest patient was 12 years old and she is now well, has a moderate scoliosis, is married, and has borne children. The oldest patient, now dead, was 64 years old at the time of operation. Table I gives more details concerning the age distribution.

TABLE I. AGE GROUPS BY DECADES

Age	10-19	20-29	30-39	40-49	50-59	64
Number of Patients	21	106	84	48	18	1
% of Total	7.5	38.1	30.2	17.3	6.5	0.4

The majority of the patients were white (258, or 92.8 per cent). There were nine Negroes (3.2 per cent) and eleven Mexicans or Indians (4.0 per cent). Two hundred thirty of the patients (82.7 per cent) had bilateral disease. Among these, the lesion in the contralateral lung was apparently active in 115

(41.4 per cent), and in three of the 115 the lesion was obviously progressive. Fifteen of the 230 had cavities visible in the so-called "better lung." Unilateral disease was present in forty-eight; twenty-two in the right and twenty-six on the left. Operation was performed on the right in 132 patients, and on the left in 146.

Among the 278 patients, positive sputum was present in 263 (94.6 per cent). Fifteen patients (5.4 per cent) had negative sputa, even though eleven of these had visible cavities by roentgenogram. The thoracoplasties of these fifteen patients were performed before 1940, and so cultures were made in only eight instances; in three only smears were used, and in four concentration of the sputa was utilized.

The amount of sputum raised by the patients varied considerably. In general, it may be stated that 157 patients (56.5 per cent) brought up less than 25 Gm. daily and thirty-one patients (11.1 per cent) raised more than 100 Gm.

One hundred eighty-nine patients (67.9 per cent) had been in the sanatorium for two years or less when their thoracoplasty was performed. Eighteen patients (6.5 per cent) were treated for three months before thoracoplasty, 36 patients (12.9 per cent) for three to six months; 75 patients (26.9 per cent) for six to twelve months; 60 patients (21.6 per cent) for one to two years; 29 patients (10.4 per cent) for two to three years; 26 patients (9.3 per cent) for three to four years; 18 patients (6.5 per cent) for four to six years; 7 patients (2.5 per cent) for six to eight years; 9 patients (3.2 per cent) for more than eight years. During this time, these patients had had, in addition to bed rest, pneumothorax (with or without pneumonolysis) or a temporary phrenic nerve interruption in a large majority of instances. Pneumoperitoneum was not used in any patient. Streptomycin, penicillin, or other antibiotic substance was not utilized either before, during or after operation.

On the side of the thoracoplasty 57 patients (20.5 per cent) had moderately advanced tuberculosis, and 221 (79.5 per cent) had far-advanced lesions. Four had exudative lesions and 87 were of the pneumonic type, while 186 were of the productive type. One patient could not be classified. The disease was limited to the apical portion of the lung in three patients; to the upper one-third in 53 patients; to the upper one-half in 55 patients; to the upper two-thirds in 75 patients; to an entire lung in 87 patients; to only the middle third in one patient; to the lower one-half in one patient; to the lower two-thirds in two patients; and one patient could not be classified.

One or more cavities were seen on the preoperative roentgenograms of 236 patients (fourteen of these patients had a complicating empyema). Among the 278 patients, cavities which were visible at one time were no longer definitely recognizable in twenty-six. Sixteen patients never had a visible cavity (planigrams were not in use at this clinic prior to 1946). A majority of patients (151, or 57.9 per cent) had one cavity. Table II demonstrates the number of cavities shortly before operation.

Table III lists the variations in the greatest diameter of the cavities. The patient with the largest cavity (12 cm.) was alive eleven years after thoracoplasty, had negative sputum cultures, and no cavity was visible on the roent-

TABLE II. NUMBER OF CAVITIES SEEN PREOPERATIVELY

NUMBER OF CAVITIES	NUMBER OF PATIENTS
None	42
1	151
2	24
3	14
4	6
5	1
More than 5	12
Moth-eaten appearance	18
Unknown	10

genogram. The majority of the cavities were round or oval and had moderate to extensive parenchymal infiltration about them. Ten of the cavities were classified as partly blocked and fluid levels could be demonstrated in all of them.

TABLE III. CAVITY SIZES

CAVITY SIZE	NUMBER OF PATIENTS
No cavity	42
Less than 1 cm.	24
Less than 2 cm.	51
Less than 3 cm.	53
Less than 4 cm.	50
Less than 5 cm.	28
Less than 6 cm.	17
6 to 8 cm.	9
8 to 10 cm.	3
12 cm.	1

In the contralateral lung, the tuberculosis was classified as minimal in 83 patients, moderately advanced in 103 patients, far advanced in 44 patients, and no disease in 48. As previously mentioned, the contralateral lesions were active in 115, and 15 patients had visible cavities. Seven additional patients had had cavities in the so-called "better lung" but they were not visible on the immediate preoperative films. The greatest number of cavities in this group was 2, and the largest was 7 cm. in diameter.

The data mentioned above are listed merely to serve as an indication of the various types of lesions found in this 278-patient group. A correlation between these data and the results is not presented since there would be too few patients for the many divisions.

Tuberculous bronchitis was noted preoperatively in 76 patients. A detailed study of this group is still being carried on even though a group this small may not be of statistical importance. Thirty of the patients had bronchial lesions on the side of the contemplated thoracoplasty which were very localized; 18 were moderately extensive; and 7 were very extensive. Ten patients had bilateral bronchial involvement with 7 of the lesions in the contralateral side described as very localized, 2 as moderately extensive, and one as very extensive. A decrease in the caliber of the involved bronchus was noted in 27 patients. The lumen of the bronchus was described as being reduced by 50 per cent or less in 17 patients, and 85 per cent to 95 per cent in 3 patients. Of the 76 patients with tuberculous endobronchitis, 53 were found at the time of this

follow-up study to be alive and 23 were dead. Of those alive, 9 patients were working full time more than ten years after operation, considered themselves well, and all but one (with intermittently positive sputum cultures) had negative sputum; 20 were well and working full time more than five years after operation and had negative sputum; 10 were well but stated that they worked part time (7 had negative sputum, one became negative after a lobectomy, and 2 had intermittently positive sputum); 5 patients stated that they were short of breath (3 had negative sputum, 2 were positive on culture only, and one of the latter had a visible cavity beneath the thoracoplasty but refused further treatment); 8 patients failed to answer the questionnaire but all had had negative sputum cultures more than five years since thoracoplasty; one patient is still in the sanatorium with positive sputum and a draining cavernostomy. Thus, of the 53 patients still alive, 46 have negative sputum cultures and 35 consider themselves well and are working. Of the 23 patients who died, 5 lived more than five years after operation, 7 lived three to five years, 5 lived one to three years and 6 lived less than one year. The causes of death in this group are listed as follows:

12 patients had a spread or exacerbation of their disease and died of progressing tuberculosis;
3 patients died of cardiorespiratory decompensation;
2 died from accidental causes (aniline dye poisoning and pontocaine poisoning during anesthesia for bronchoscopy);
1 died as a suicide;
2 died from tuberculous meningitis;
1 died of a bronchoesophageal fistula which required gastrostomy;
1 died from the combination of an infected wound and atelectasis; and
1 died from an unknown cause.

To compare the results with the other patients who did not have tuberculous bronchitis would be misleading since these seventy-six patients are a highly selected group in which the types of tuberculous bronchitis that would contraindicate thoracoplasty are not represented.

The Semb extrafascial apicolysis was added to the thoracoplasty in 63 patients. Of these, 21 are dead and 42 are alive. An attempt was made to perform this procedure in 6 additional patients, but it was not possible to do so. Of these 6 patients, 5 are alive and one dead (not as a direct result of the attempt). Five patients in whom the Semb apicolysis was performed developed infection in the subscapular space and two of these are alive. We cannot be at all certain that the infections were a direct result of the procedure, since other factors which might have contributed toward the infection were present in all the patients.

In a majority of the 278 patients the indication for the thoracoplasty was cavitary disease (216 or 77.7 per cent). Other indications were: failure of pneumothorax (or any other treatment) to control the disease (no cavity being visible), 35 patients (12.6 per cent); empyema with a cavity in the lung, 16 patients or 5.7 per cent; empyema without parenchymal cavity, 7 patients or

2.5 per cent; to obliterate an extrapleural space (not empyema), 2 patients or 0.7 per cent; repeated hemoptysis (sputum negative), one patient; unexpanded lung under pneumothorax space, one patient.

The number of ribs removed varied according to the extent and type of the lesion. Table IV lists the number of ribs from which segments were removed.

TABLE IV. EXTENT OF THE THORACOPLASTY

NUMBER OF RIBS	NUMBER OF PATIENTS
3	13
4	20
5	25
6	29
7	67
8	72
9	31
10	16
More than 10	5

To obtain better collapse where fewer than seven ribs were removed, a portion of the scapula was removed in 31 patients. A complementary anterior thoracoplasty of the Haight type[3] was performed in 158 of the 278 patients. The majority of these included three or four ribs (144), but in 4 patients two ribs were removed, in 5 patients five ribs were removed, in 2 patients six ribs were removed, and in 3 patients seven ribs were removed. Formalin (10 per cent) was applied to the periosteum after the ribs were removed in order to delay or prevent regeneration of the periosteum. This was done in all cases only in the area between the axillary border of the scapula and the bases of the transverse processes. Care was exercised not to apply the formalin anterior to the axillary border of the scapula where it might result in a soft chest wall and complicate the postoperative convalescence. In practically every instance the interval between stages was three weeks. In a large majority of patients the anesthetic agent was nitrous oxide-oxygen-ether, supplemented by intercostal nerve block with 1 per cent procaine.

Accidents occurring during operation were few. The parietal pleura was torn in six patients; the internal mammary artery and vein and the first intercostal artery were each torn once; a root of the brachial plexus was injured once (recovery was complete); and an empyema space was entered once.

Postoperative convalescence was studied under two headings; parenchymal and extraparenchymal. In the former category, atelectasis occurred on the side of operation in 2 patients, spread or reactivation of the disease occurred in 34 patients. A detailed report on this subject has been made by Yang and Lees[4]; two-thirds of the patients survived the spread, and about one-third died. The extraparenchymal complications consisted of: pleural effusion on the side of the thoracoplasty in 6 patients; effusion on the contralateral side in 3 patients; empyema on the side of operation in 3 patients; tuberculous wound infection in 6 patients; pyogenic wound infection in 25 patients (many of these were localized stitch abscesses which healed readily); wound hemorrhage shortly after operation (controlled with pressure dressings) in 2 patients; a febrile

postoperative course (no pus noted) in 6 patients. Scoliosis at the time of follow-up was minimal in 59 patients, mild in 66 patients, moderate in 104 patients, severe in 19 patients, and none was noted in 30 patients. None of the patients with severe scoliosis was disabled by it.

Seventy-five (27.0 per cent) of the 278 patients are dead. Twenty-three of these died more than five years after thoracoplasty. Table V lists the time of death after the last stage of the operation, and Table VI lists the causes of death.

TABLE V. TIME OF DEATH AFTER OPERATION

LENGTH OF TIME	NUMBER OF PATIENTS
Less than 3 months	10
3 to 6 months	8
6 to 12 months	5
1 to 2 years	10
2 to 3 years	8
3 to 5 years	11
5 to 13.5 years	23

TABLE VI. CAUSES OF DEATH

Progressive tuberculosis on unoperated side	17
Exacerbation of lesions on operated side	9
Spread to lung on operated side	6
Cardiorespiratory decompensation	14
Extrapulmonary tuberculosis	6
Nephritis and amyloid disease	4
Tuberculous meningitis	3
Suicide	3
Accidental death by poisoning	2
Operative complications	2
Extrapulmonary carcinoma	2
Leucemia	1
Unknown	6

Thus, from Table VI we note that 17 patients died of progressive tuberculosis in the lung on the unoperated side, 15 patients died of progressive tuberculosis of the operated side, and 14 of cardiorespiratory decompensation. Among the 6 patients who died of extrapulmonary tuberculosis, 4 had active pulmonary lesions and 2 appeared stable shortly before death. Tuberculous meningitis claimed 3 patients; one died six weeks after the last stage of his thoracoplasty; thoracoplasty was performed for a second patient to prevent continued seeding of lesions on the better side which were clearing satisfactorily, but a spread and reactivation occurred. Death from the meningitis came three months afterward; the third patient died four months following the last stage of his thoracoplasty. Death from poisoning occurred in one patient from absorption of aniline dye used industrially and in another patient during anesthetization with pontocaine solution prior to a check-up bronchoscopy for a previously existing tuberculous bronchitis. One of the two deaths from operative complications occurred in a patient who was having a thoracoplasty performed over a previously performed extrapleural pneumothorax which did not control the tuberculosis. A bronchopleural fistula developed and was listed as

the cause of death; the other death was due to bilateral atelectasis in a patient who would not or could not cooperate in raising his sputum and died twenty-four hours after operation.

Thirty-three patients died twenty-four hours to two years after the thoracoplasty; 15 from progressive tuberculosis after an exacerbation or spread; 6 from cardiorespiratory decompensation; 3 from tuberculous meningitis; 2 from operative complications; 2 from suicide; 1 from nephritis and amyloidosis; and 4 from unknown causes.

Forty-two patients died at varying intervals from two years to thirteen and one-half years. The patient, who lived thirteen and one-half years after operation, died of carcinoma of the uterus. Eight patients died two to three years after operation (3 from progressive tuberculosis in the unoperated lung, one from an exacerbation in the operated side, 2 from cardiorespiratory decompensation, 1 as a suicide, and 1 from nephritis and amyloidosis); 11 patients died three to five years after operation [8 died from nontuberculous causes as follows: cardiorespiratory decompensation (1), accidental poisoning (2), acute appendicitis (1), neurosyphilis (1), pneumonia (1), leucemia (1), and hypertensive heart disease (1); and 3 died from progressive tuberculosis]; 23 patients died in from five to thirteen and one-half years (10 from progressive tuberculosis, 4 from cardiorespiratory decompensation, 1 from intestinal tuberculosis, 1 from a cerebral-vascular accident, 1 from a bronchoesophageal fistula, 1 from hypertensive heart disease, 1 from a nontuberculous pneumonia, 2 from extrapulmonary carcinoma, 1 from severe diabetes, and 1 from an unknown cause). Of this last mentioned group of 23 patients 11 were discharged from the sanatorium as apparently arrested, and later died of nontuberculous causes. Four were discharged against medical advice with quiescent disease, and later died of progressive tuberculosis; 4 were discharged as apparently arrested and died later of reactivated lesions; 1 was discharged as quiescent (intermittently positive sputum cultures) and died later of intestinal tuberculosis; and 3 patients were never discharged and died in the sanatorium of tuberculosis.

Nineteen of the 75 patients who are dead had negative sputum at the time of the follow-up examination. However, 11 of these 19 had pulmonary or intestinal lesions which appeared active by x-ray examination. We can say, therefore, that only 8 of the 75 patients probably had truly negative sputum. The causes of death listed for these 8 patients are: carcinoma of the uterus, 1; severe diabetes, 1; nontuberculous pneumonia, 1; cerebral-vascular accident, 1; and cardiac disease, 4.

If we consider three months after operation as the maximum period of time during which death may be attributed directly to the thoracoplasty, there were 10 such patients, an early mortality of 3.6 per cent. Among the 65 patients who died more than three months after operation, 26 (9.4 per cent of 278 patients) died of nontuberculous causes, 33 (11.9 per cent of 278 patients) died of tuberculous causes, and 6 died of unknown causes.

Of the 203 living patients, 6 had lesions which never healed. Three of these were bronchoscoped and 2 were demonstrated to have tuberculous bronchitis. The third patient was believed to have an invisible cavity, and eight

years after thoracoplasty had a lobectomy with prompt conversion of the sputum and persistently negative cultures, during the one and one-half years since the lobectomy. This patient is, of course, considered as a thoracoplasty failure. Three patients were not bronchoscoped; two of them had had blocked cavities preoperatively, and tuberculous bronchitis was suspected as the cause of the unhealed lesions. The third patient was known to have tuberculous bronchiectasis.

Interpretation of the roentgenograms of the 203 living patients from five to fifteen years after the last thoracoplasty stage showed that 181 (65.1 per cent) of the whole group of 278 patients and 89.1 per cent of the 203 living patients apparently had inactive lesions, and without cavitation. Twenty-two patients apparently had roentgenologically active lesions.

One hundred seventy-four patients had negative sputum cultures at the time of the follow-up examinations (62.5 per cent of the whole group of 278 and 85.7 per cent of the 203 living patients). These figures include 23 patients who had no sputum (although when it had been present it was negative on three successive monthly cultures) and who did not have follow-up cultures of gastric contents either because they refused or because it seemed impractical to require them to go without breakfast, or without breakfast and lunch before making a more or less long trip to the sanatorium Outpatient Department. In addition to the 174 negative patients, there were 8 patients who died from causes unrelated to tuberculosis (as listed above) and whose follow-up cultures had been negative; if these 8 are added to the 174, as we believe they should be, 182 (65.4 per cent of the whole group of 278 patients and 89.6 per cent of the 203 living patients) have or had negative cultures.

Upon reviewing the patients' answers to the questionnaires certain information was gathered. Nineteen patients, however, failed to answer or sent inadequate answers; we learned indirectly that 5 of them were apparently well and were working; the data about these 19 patients were therefore obtained from the records of their last examinations, all of which were five years or more after operation.

Among the 203 living patients, 134 (66.0 per cent) considered themselves well, and they were doing full-time work. Forty-four additional patients also considered themselves well but 23 (11.3 per cent) were doing only part-time work and 11 (5.4 per cent) stated they could not work (the majority of these were more than 60 years of age). Ten patients were still in the sanatorium when the study was completed; several of them have since had resection operations, the results of which are not included in this report. Six patients are living but not well; 3 of these six patients have negative sputum and apparently healed lesions by roentgenogram, but they are dyspneic.

Since the study was completed in 1949, we did not utilize the 1950 NTA classification. Utilizing the National Tuberculosis Association's classification in force prior to 1950, the 278 patients may be listed as follows:

Apparently cured	140 (50.3 per cent)
Arrested	9 (4.3 per cent)
Apparently arrested	36 (12.9 per cent)

Quiescent	2 (0.7 per cent)
Improved	11 (3.9 per cent)
Worse	5 (2.0 per cent)
Dead	75 (27.0 per cent)

SUMMARY

1. Two hundred seventy-eight patients who had the modern type of thoracoplasty were followed from five to fifteen years after operation.

2. Little difference was noted with regard to sex or side of operation, there being about 50 per cent of each.

3. No streptomycin or penicillin was used in the group either before or after operation.

4. The major indication for thoracoplasty was cavitary tuberculosis.

5. Seventy-six patients had tuberculous bronchitis; 53 of these patients are alive (46 have negative sputum); 23 patients are dead (5 lived more than 5 years after operation).

6. Spread or reactivation of disease occurred in 34 patients. Of these about two-thirds survived and one-third died.

7. Seventy-five (27.0 per cent) of the 278 patients are dead.

8. Two hundred three patients are living; 174 (85.7 per cent) of them have negative sputa. If the 8 patients who died from nontuberculous causes but who had negative sputa are added, the figure is 89.6 per cent of the 211 patients.

9. According to the NTA classification in use when this study was completed (1949), the 278 patients may be listed as follows: apparently cured, 140 or 50.3%; arrested, 9 or 4.3%; apparently arrested, 36 or 12.9%; quiescent, 2 or 0.7%; improved, 11 or 3.9%; worse, 5 or 2.0%; dead, 75, or 27.0%.

We wish to express our appreciation to Dr. Edward W. Laboe, formerly director of the Michigan State Sanatorium, for his splendid cooperation in placing at our disposal the laboratory and clerical facilities required. In addition, acknowledgement is made of the services of the late Dr. Edward Finch who examined those patients who returned to the Outpatient Department of that sanatorium and who aided in the interpretation of the films mailed to the sanatorium.

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DISCUSSION

COL. JAMES H. FORSEE, Denver, Colo.—This splendid paper so well presented by Dr. Lees is a distinct addition to our information relative to follow-up data pertaining to thoracoplasty. We have recently undertaken an attempted survey of thoracoplasties performed over a long period, from 1927 through 1946. This, of course, represents various types of thoracoplasties performed during those years, and we have had the very valuable assistance of the National Research Council in making this follow-up study.

(Slide.) There is a total of 514 patients, military personnel, who have been followed at a 97 per cent follow-up rate. There is one thing very positive in the interpretation of such data and that is whether or not the patient is dead or alive. Forty-seven per cent of the entire group are dead.

(Slide.) Following the era of streptomycin, beginning in 1947, we have the following data, of course in a much shorter follow-up period, and doubtless as we continue to follow these patients we will find that more and more deaths will be added to that column. However, of 172 patients operated on in 1947 and 1948, 9 per cent are dead. If we eliminate those operated on for tuberculous empyema the death rate is 6 per cent.

We have employed the type of thoracoplasty standardized by Dr. Alexander and his group, and we have not found it desirable to date to combine thoracoplasty at the time of lobectomy.

DR. ROBERT PANNIER, Bruges, Belgium.—I am very grateful to the Association for allowing me to take part in this discussion.

In relation to Dr. Lees' very interesting paper, I should like to say a few words on the late results of thoracoplasty as they came out of a recent follow-up of 1,137 cases operated upon between 1926 and 1948, in the chest department run by Dr. DeWinter at the St. John's Hospital in Bruges (see *Acta Tuberc. Belgico,* 1950). In so far as indications and operative technique are concerned, this is a very uniform group because all the cases have been selected by one man, Dr. DeWinter, and were operated upon by only two surgeons, the late Professor Sebrechts, until 1948, and then by one of his former assistants, Dr. Deems.

The technique has changed very little since 1930. Time does not permit me to go into details. However, I should like to stress two points: first, statistics compiled year by year show that in the group of patients who have successfully undergone thoracoplasty (this means that they were still alive three months after operation) most of the later deaths occurred in the first three years following the operative procedure. These figures are naturally more severe in the poor risks than in the good risks. Those who have successfully undergone that period of consolidation, as we call it now, may expect a long survival.

7 patients are alive for more than 23 years
9 patients are alive for more than 21 years, and
7 patients are alive for more than 20 years.

These were not all good risks and it is interesting to note that of that small group of 22 patients, 4 were poor risks, 5 severe cases with extensive bilateral disease, and 3 had a bronchopleural fistula with empyema.

In 1949, the results for the entire group of 1137 were as follows:

Of the good risks	70 per cent are alive for 23 to 3 years after operation
Of the moderate risks	57 per cent
Of the poor risks	27 per cent
Of extensive bilateral disease	33 per cent
Of bronchopleural fistula and empyema	26 per cent

The second point I should like to stress is that those who die after that three-year consolidation often die of tuberculosis, but not necessarily of pulmonary tuberculosis. Some have been well and working for ten to twelve years after operation.

I am very sorry not to be able to show the photograph of a group of 31 patients who were presented at a meeting in 1931, who had had their thoracoplasty one to four years previously. I have no slide with me, as I did not expect to have an opportunity to present it here, and there is unfortunately no epidiascope available. In 1950, 22 of these 31 patients are still alive and well, now for more than nineteen years. Of the 9 who died, one died in an accident in 1935; one died of heart failure in 1945; and seven died of tuberculosis

1 after 7 years
1 after 9 years

2 after	10 years
1 after	11 years
1 after	12 years
1 after	17 years

This shows that we do not always cure the patient—in many cases we only arrest the disease; sometimes, however, for many, many years.

DR. CAMERON HAIGHT, Ann Arbor, Mich.—As you know, Dr. Alexander's group has been very much interested in the subject of thoracoplasty. We believed when this study was undertaken that it would be timely to learn the late results of thoracoplasty, particularly in view of the increasing use of pulmonary resection, so that it would enable a comparison of the late results of thoracoplasty with at least the early results of resection. There are two points that I would like to stress in connection with the cases Dr. Lees has presented.

It is well known that the results of thoracoplasty can be considerably influenced by the selection of cases that give the most promise of success. In this regard I would like to say that the cases which Dr. Lees has shown have been chosen not because it was felt that they would necessarily obtain a good result, but in a number of instances because nothing else could be done. We have often accepted what we consider to be extremely poor risks for thoracoplasty, including patients with a very low respiratory reserve in whom it was problematic if the desired amount of collapse could be obtained. It is interesting, then, to see the late results in cases which include many substandard indications.

In the evaluation of any type of therapy for tuberculosis, the longer the cases are studied the less satisfactory the results will be. This was the reason that patients operated on in the last five years have not been included, as it was desired to study only late results. This series illustrates the decreasingly favorable results with the passage of time and, therefore, the results cannot be compared with those obtained within three to five years after operation.

At the present time we continue to rely greatly on the use of thoracoplasty in the treatment of pulmonary tuberculosis. The actual number of cases of thoracoplasty, however, is less than formerly, inasmuch as approximately one-half of the patients for whom major surgery is indicated are now treated by resection. A problem which bothers us greatly at present—and I believe that the answer has not yet been reached—is the choice of procedure in the treatment of large inflation cavities; that is, whether resection should be done or whether they should be treated by thoracoplasty with the hope that the thoracoplasty will be effective. At present, we are using the latter plan with certain exceptions, thereby reserving resection for those cases in which thoracoplasty has failed.

DR. LEES (closing).—I wish to thank the discussors. Unfortunately, time did not permit going into great detail about the causes of death; they will be listed in the paper.

With regard to Dr. Pannier's mention that the late cause of death in the majority of instances in his study was due to tuberculosis, our results are not entirely thus. Approximately one-third of the patients died within a year, those deaths being due, in the main, to progressive tuberculosis. Approximately one-third of the patients died within one to three years, in the majority of instances from tuberculous causes. The rest of the patients, 34, died three years or more after thoracoplasty. Of these last mentioned patients, 10 died of tuberculosis; eight from progressive tuberculosis in the contralateral lung, and two from reactivated tuberculosis beneath the thoracoplasty.

SIMULTANEOUS DECORTICATION AND RESECTION IN UNSUCCESSFUL PNEUMOTHORAX

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THE problem of unexpandable lung after pneumothorax and its complication, tuberculous empyema, is a serious one. Review of the literature reveals that 50 to 70 per cent of all pneumothoraces develop fluid at some time.[18, 23] Furthermore, following pneumonolysis, about 50 per cent of the patients develop more or less persistent fluid.[13] The irritating effect of this fluid results in the development of a fibrous membrane on the visceral and parietal pleuras which sometimes prevents re-expansion of the lung, when pneumothorax treatment is discontinued. The incidence of unexpandable pneumothorax has been quoted as 5 to 10 per cent.

Accepting the philosophy of Robin[23] that all pleural effusions in tuberculous patients have a tuberculous etiology and that adequate search will reveal organisms, it is not surprising that 15 to 20 per cent of such effusions develop finally into empyema.[18, 23] Similarly, following pneumonolysis, about 6 per cent of cases go on to tuberculous empyema.[13] This tuberculous empyema membrane likewise prevents re-expansion of the lung and results in marked impairment of function of diaphragm and chest wall. A further serious complication of empyema is the development of bronchopleural fistula which, due to aspiration of empyema fluid, often leads to contralateral spread and ultimate fatality.

Following discontinuance of pneumothorax, the lung frequently does not re-expand appreciably in these complicated cases. The pleural space, and rarely the empyema space, may be obliterated, but this is accomplished more by the shift of the mediastinum, elevation of the diaphragm, and flattening of the chest wall than by lung re-expansion per se. The disadvantages of such a mechanical situation are well known. They are overdistention of the contralateral lung with associated danger of reactivation; dysphagia due to retraction of the esophagus; deformities of the thorax; and last but not least, limitation of respiratory function. Therefore the mere obliteration of pneumothorax space is not always the desired end.

Previous attempts at solving these problems resulting from pneumothorax complications have not always been satisfactory. Thoracoplasty has been successful if the membrane preventing re-expansion has been thin. Here, however, considerable healthy lung is collapsed and thus lost from function in achieving obliteration of the space. More often, however, a total thoracoplasty is not successful in completely obliterating the space when the membranes are

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thick, as is usually the case in tuberculous empyema. Even if they are in contact, the opposing surfaces will frequently not fuse because of avascularity of the membranes and the presence of tuberculous granulations and caseous areas in them. When active parenchymal disease persists in the unexpanded lung and is covered by a dense membrane, it can seldom be collapsed further by thoracoplasty. Thus thoracoplasty has little or no effect on active disease under these circumstances, as well as little or no effect on obliterating the residual space.

Schede thoracoplasty has also been used to attempt to obliterate tuberculous empyema when thoracoplasty alone was unsuccessful or when bronchopleural fistula was present. This operation is a mutilating procedure with considerable resultant deformity of the chest wall. It is a bloody and shocking operation with a high operative mortality, requiring multiple procedures, and carrying a considerable morbidity. The operation, therefore, is conscientiously avoided by most thoracic surgeons.

Decortication as the modern concept of the treatment of unexpandable lung with its complications has evolved from the contributions of various surgeons in the past. Great impetus was given by the experience of surgeons in World War II with chronic clotted and infected hemothorax. The principles of decortication were then applied to other forms of chronic unexpandable lung such as chronic nontuberculous spontaneous pneumothorax and pyogenic empyema.[1] These rapid strides in development were aided by improvements in technique, anesthesia, blood replacement, and antibiotics. With the establishment of the value of decortication in nontuberculous conditions on a firm basis, it was but a short step to apply the same principles to the unexpandable tuberculous lung.

PATHOLOGY

The pathogenesis of the unexpandable lung is well recognized, and has been clearly stated by Weinberg and Davis.[7] The pathologic changes may vary greatly, and for our purposes five points will be discussed briefly. First is the earliest stage of the unexpandable lung with opacity of the pleura without other gross change. Microscopically it is a thin fibrinous membrane richly vascularized and infiltrated with leucocytes and histiocytes. This is probably a reversible phase. There is the later second stage when a gross membrane becomes visible which may vary from 2 to 3 mm. in thickness in the visceral layer and from 3 to 10 mm. in thickness in the parietal layer. On microscopic examination there is a hyalinized fibrous middle layer with avascular peripheral layers. Although typical tuberculous lesions may be found in all layers, they are not always present. The fluid in the space may be clear or turbid and may or may not contain tubercle bacilli. A pleural endothelial layer may be recognized. This stage is usually irreversible. In the third stage frank empyema may be present with a thick membrane lined by fibrinous and caseous exudate. Microscopically there is an absence of an endothelial layer, but there is a hyalinized middle layer of the membrane showing all stages of inflammation and degeneration from endothelial tubercles to caseation and calcification. This membrane may be densely adherent by fibrosis to pleura and lung. The sac

usually contains purulent fluid from which tubercle bacilli can readily be isolated. Fourth, the membrane, because of its constricting nature, may produce infolding of the lung. This, plus collapse, does not produce parenchymal fibrosis, but fibrosis when present is related to the inflammatory process in the parenchyma and not to the collapse per se. Fifth, the parenchymal pathology will depend upon the state of activity of the tuberculosis. This pathologic picture is well known and does not warrant repetition here.

INDICATIONS AND CONCEPTS OF TREATMENT

The indications for decortication in pulmonary tuberculosis have been discussed frequently in the past few years[3-10] and involved primarily arrested or healed parenchymal disease associated with an unexpandable lung. We accept these as indications for decortication, but believe that there are other fundamental principles which must also be considered. Of primary importance in any case is the status of the underlying lung. Here must be considered the bacillary content of the sputum, activity of the tuberculous focus, and the extent of parenchymal involvement. A positive sputum established as arising from the encased lung is a warning that simple decortication will not be definitive, and further may be disastrous by way of spread. The uncontrolled parenchymal focus assumes major significance here and its treatment must be a part of the total therapeutic plan.

Extent of parenchymal involvement prior to induction of therapeutic pneumothorax should always be defined prior to decortication. Large necrotic and cavitary foci, seemingly arrested by pneumothorax, may reactivate upon decortication. Likewise extensive caseous foci may produce localized peripheral fibrosis between peel and lung, thus technically preventing decortication. This consideration must be a part of the total therapeutic plan.

Further, widespread parenchymal involvement may produce sufficient fibrosis to prevent maximum re-expansion postoperatively, resulting in failure to fill the pleural space. This situation, as is well known, predisposes to increase postoperative complications and decortication failures. Thus the relationship of pleural space to available lung volume must be a part of the total therapeutic plan.

The importance of these fundamental principles in the preoperative analysis of the case has resulted in a reclassification of indications for decortication in tuberculosis, as shown in Table I, and concepts in treatment in Table II.

TABLE I. INDICATIONS FOR DECORTICATION IN TUBERCULOSIS

I. Successful pneumothorax—sputum negative
A. Peel, with or without fluid
B. Tuberculous empyema
II. Unsuccessful pneumothorax—sputum positive
A. Peel, with or without fluid
B. Tuberculous empyema with or without bronchopleural fistula
III. Tuberculous pleurisy with effusion (spontaneous)
A. Unexpanded lung
B. Empyema

TABLE II. CONCEPTS IN TREATMENT

I. Successful pneumothorax	
Complete re-expansion undesirable or impossible because	
A. Extensive parenchymal disease—danger of reactivation	
B. Perpendicular fibrosis (lung—peel)	
Treatment:	1. Preliminary tailoring thoracoplasty
	2. Decortication—uninvolved lung only
II. Unsuccessful pneumothorax	
Uncontrolled parenchymal disease	
Treatment:	1. Preliminary tailoring thoracoplasty—except in segmental or block
	2. Resection—block, segmental, lobe or lung
	3. Decortication uninvolved lung

In respect to indications, the first group includes those cases usually accepted as an indication for decortication, namely, unexpandable lung with parenchymal disease arrested and sputum negative. In this group we have, however, made an important subdivision distinguishing those arrested or healed cases with such extensive parenchymal involvement prior to the therapeutic pneumothorax that re-expansion of the involved areas is not desirable because of danger of reactivation. It is believed that here permanent collapse is necessary to insure stabilization of the diseased area. One author has indicated that in a statistically significant series of pneumothorax follow-ups it was determined that where the parenchymal cavity is more than 4 cm. in diameter, the expected cure rate by pneumothorax treatment will not be over 4 per cent. It is this group of patients in whom we believe that permanent collapse should be instituted to insure the future health. Also the extensive disease may have resulted in such widespread fibrosis of peel to parenchyma that decortication is technically difficult if not impossible, and in such a case a tailoring thoracoplasty is necessary to obliterate residual pleural space. In this situation preliminary tailoring thoracoplasty is done and usually consists of subperiosteal resection of the first two and shorter portions of the third and fourth ribs. As soon as the chest wall is stabilized (in three to four weeks) decortication of the healthy portion of the lung is carried out leaving the diseased areas untouched.

The second basic division of cases of unexpandable lung includes those with positive sputum due to a varying extent of active uncontrolled pulmonary disease despite the adequate anatomical collapse of a pneumothorax. Permanent collapse by thoracoplasty is not indicated, since apparently adequate collapse by pneumothorax was ineffective in controlling the disease. Further, thoracoplasty sufficient to collapse the diseased area maximally would needlessly collapse healthy lung tissue. In these cases, preliminary tailoring thoracoplasty is at first performed if more than a block or segmental resection is contemplated. After the same short interval resection of the involved parenchyma is done and the healthy portions of the lung are decorticated. If pneumonectomy is necessary, due to bronchial disease or destroyed lung, it is done without prior thoracoplasty together with resection of empyema sac if present. Thoracoplasty follows after a short interval (three to four weeks) to diminish the size of the pleural cavity. In both of these basic groups the presence of tuberculous empyema rather than sterile fluid and fibrous peel does not alter the treatment.

The third and minor group is the occasional instance when the ordinary spontaneous tuberculous pleurisy with effusion is not absorbed as usual but goes on to the development of unexpanded lung or empyema. In these cases parenchymal foci usually are not demonstrable and sputum is negative. The treatment here is simple decortication of the lung and chest wall, and occasionally a small parenchymal focus may be found subpleurally which may be resected.

OBJECTION TO DECORTICATION

There have been several objections voiced to decortication. First has been the fear of reactivation of the parenchymal tuberculous focus after re-expansion. Since pneumothorax was originally intended as a reversible procedure, and if it had been applied on sound indications, then this type of surgical re-expansion should be no more dangerous than the usual medical methods. Areas of extensive prepneumothorax disease should not be decorticated but should be kept collapsed permanently. It is undesirable to re-expand these areas and then treat them after reactivation occurs, but rather thoracoplasty as a tailoring procedure should be utilized followed by decortication of the healthy areas. Likewise in the case of persistent active disease the excision of this collapsed, but uncontrolled, disease is indicated combined with decortication. Tailoring thoracoplasty may also be indicated here. Again the importance of considering the extent and activity of the parenchymal disease prior to decortication is emphasized.

Second, the fear of chest wall infection resulting from entering tuberculous tissue perhaps has been a deterent to the operation. Experience, however, has shown that it rarely occurs. Likewise residual empyema is an infrequent complication. These complications have been minimized by the use of streptomycin and by obtaining complete re-expansion postoperatively as soon as possible. In this latter connection the use of preliminary tailoring thoracoplasty in selected cases is advantageous in addition to its value in regard to maintaining permanent collapse of extensive parenchymal lesions. Even with pneumonectomy and empyema resection, which occasionally of necessity is incomplete, residual empyema is uncommon. Parenthetically it should be said that all such procedures are followed by thoracoplasty to attempt to decrease pleural cavity volume.

TECHNIQUE

After careful study of a case, especially review of prepneumothorax roentgenographs, has satisfied our criteria for decortication, preoperative preparations include several details. Bronchoscopy is indicated to rule out bronchostenosis as an etiology for the failure in re-expansion. Streptomycin and PAS, if not already being administered, are given for at least one week and penicillin for four days preoperatively. Evaluation of the general condition is, of course, essential.

Operation is performed under general anesthesia using a posterolateral approach. The sixth rib is usually resected subperiosteally and a short posterior segment of an adjacent rib is also resected if the chest wall is rigid. In

all cases it has been possible to excise parietal as well as visceral membrane. A cleavage plane can usually be developed between parietal peel and chest wall. This plane is relatively avascular and the peel strips easily laterally and anteriorly, but with greater difficulty at the point of reflection from visceral to parietal membrane. This is especially true at the posterior apex and the costophrenic angle. Excision of the parietal peel results in a more complete removal of tuberculous tissue in the case of empyema and in the return of more normal motion of the chest wall and diaphragm postoperatively.

Next, decortication of normal lung is done in the usual manner while the lung is partially inflated. Areas of diseased parenchyma previously planned for excision or permanent collapse are not decorticated. Excision is then carried out by individual ligation technique. Decortication and segmental type resection both produce raw surfaces with leakage of air, but since the resultant minute leaks are, for the most part, transient, no attempt at repair is made. When visible bronchiolar openings are present they are repaired. In those cases where preliminary tailoring thoracoplasty has been performed, the decorticated normal lung readily fills the pleural space without overdistention.

Adequate drainage for both air and fluid is of utmost importance in achieving early and complete re-expansion and associated obliteration of pleural space. One large (one-half inch wide diameter) fenestrated tube is placed through a stab wound inferiorly in the posterior axillary line. A second tube (a fenestrated No. 22 catheter) is placed to the apex of the pleural cavity through an anterior stab wound. Both tubes are connected to individual water-seal bottles. In selected cases active suction of 15 to 20 cm. of water is used, but generally simple water-sealed drainage has been satisfactory.

Postoperative streptomycin and PAS treatment is continued for a variable length of time and penicillin for seven to ten days. Of utmost importance is the prompt removal of tracheobronchial secretions. This is accomplished most satisfactorily by cough, but if cough proves ineffective, catheter tracheal suction is used as frequently as indicated. Bronchoscopy is seldom necessary, but may be resorted to. This removal of tracheobronchial secretions prevents development of localized atelectasis and, of course, insures prompt re-expansion and obliteration of pleural space.

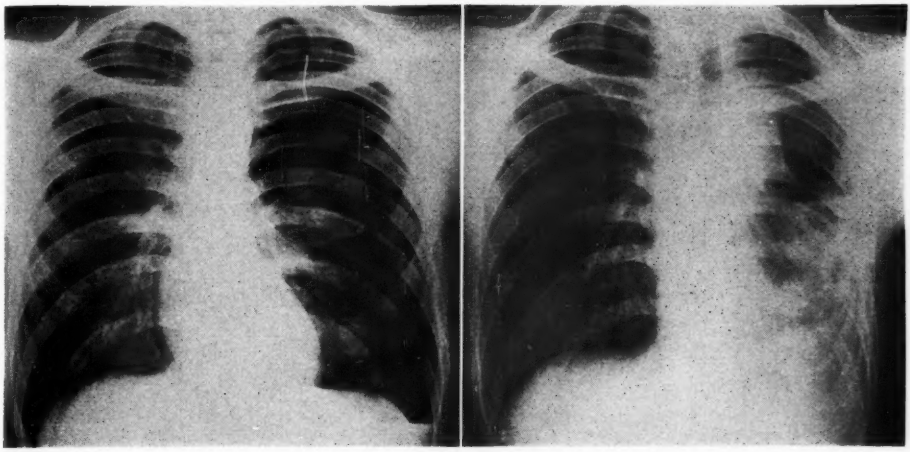
RESULTS AND CASE REPORTS

Results in this series of fourteen cases are set forth in Tables IIIA and IIIB. A case illustrative of each indication in groups one and two is summarized briefly below:

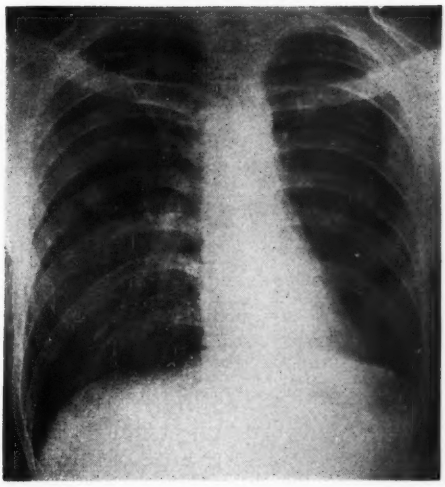
CASE REPORTS

CASE 1 (Fig. 1 *A*, *B* and *C*.).—W. L., a 30-year-old white man, whose tuberculosis was diagnosed while in the Army in 1944. Left therapeutic pneumothorax was started in May, 1945, with pneumonolysis in July, 1945. He was ultimately discharged from the Army. In July, 1948, it was decided to abandon the pneumothorax. The left lung failed to re-expand, and increasing amounts of fluid developed. Aspiration of this fluid was done many times, and all laboratory findings were negative for tubercle bacilli. Decortication was done on Mar. 10, 1949, and postoperative convalescence was uneventful. He was

discharged in July, 1949, gradually increased his activities, and at the present time he is working full time as an insurance agent. Sputum has remained negative by all methods including culture.



A. *B.*



C.

Fig. 1.—*A*, Left pneumothorax. *B*, Unexpandable left lung; sputum, negative. *C*, After left decortication and re-expansion; sputum, negative.

This represents a case of moderately advanced original disease successfully treated with pneumothorax but complicated by unexpandable lung. Treatment here is simple decortication and re-expansion.

CASE 2 (Fig. 2 *A*, *B*, *C* and *D*.).—P. B., a 22-year-old white woman. Tuberculosis was diagnosed in 1943 and, after a short period of bed rest, right pneumothorax was begun in July, 1943. Fluid developed soon after the induction of the therapeutic pneumothorax. It was clear at first but soon became purulent, and was positive repeatedly for tubercle

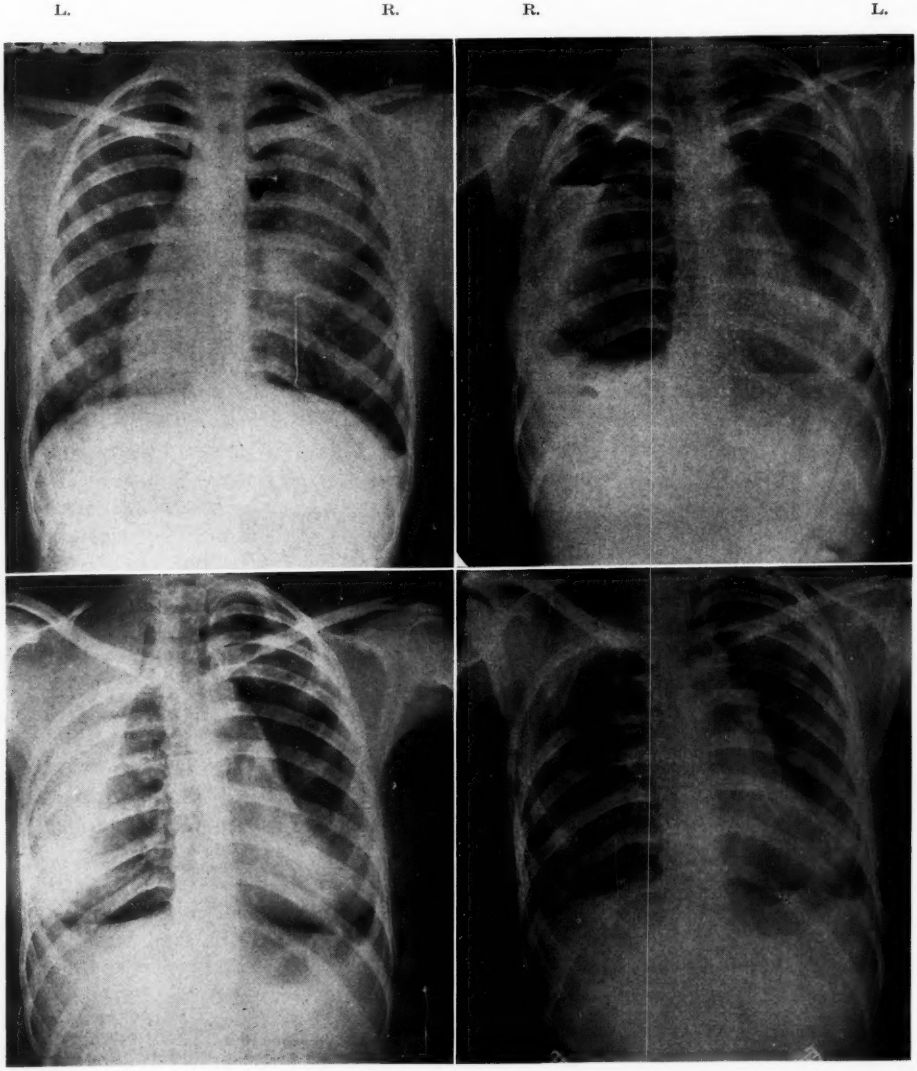
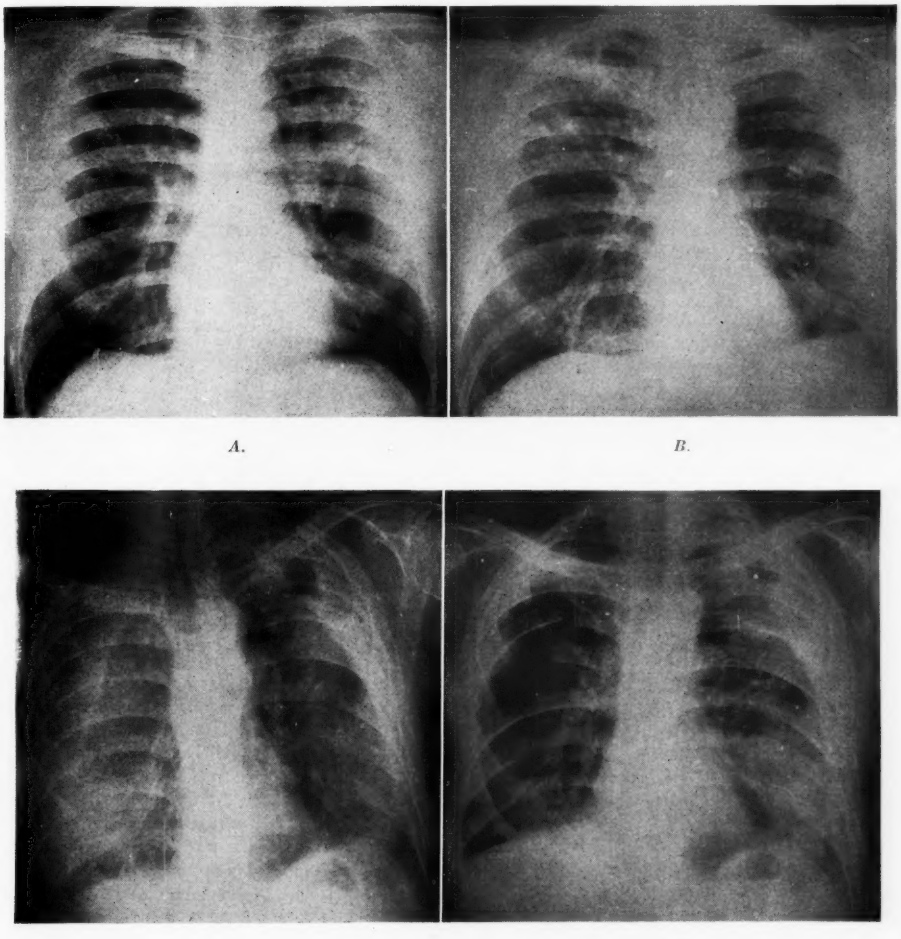


Fig. 2.—*A*, Right pneumothorax. Extensive right upper lobe disease with patent cavity. *B*, Unexpandable right lung with tuberculous empyema. Cavity closed and sputum negative. *C*, After preliminary tailoring right thoracoplasty. *D*, After decortication of right middle and right lower lobe. Right upper lobe premanently collapsed; sputum, negative.

bacilli. A left pneumothorax was begun in 1945 and was abandoned in August, 1949. Sputum had been negative on concentrate and culture since 1947. A preliminary tailoring thoracoplasty was done on June 16, 1950, consisting of the subperiosteal resection of the first and second, and shorter portions of the third and fourth, ribs. The transverse processes were not removed. Decortication of the right middle and lower lobes was done on July 14, 1950. The right upper lobe was not decorticated, and the liberated middle and lower lobes nicely filled the pleural cavity. The postoperative course was uncomplicated with sustained expansion of the middle and lower lobes, and the sputum has remained negative by all methods to date.



A. *B.*

C. *D.*

Fig. 3*A-D.*—*A*, Extensive left lung disease; left lung unexpandable. *B*, Right upper lobe disease appears. Left lung remains partially collapsed. *C*, bilateral unexpandable lungs with bilateral tuberculous empyema; sputum, negative. *D*, After right decortication; function much improved; sputum, negative.

This patient had extensive right upper lobe disease successfully treated by pneumothorax, but complicated by tuberculous empyema and unexpandable lung. Because of the original extensive disease, re-expansion of which was considered dangerous, thoracoplasty to maintain right upper lobe collapse, and decortication of the right middle and lower lobes were combined.

CASE 3 (Fig. 3 *A*, *B*, *C*, *D* and *E*.).—H. B., a 43-year-old man, first developed tuberculosis in 1932. In 1933 a left pneumothorax was induced for cavitary disease in the left upper lobe, with considerable surrounding infiltration. Pneumothorax was maintained until 1936. Following attempted re-expansion there was a considerable amount of fluid and pleural thickening, and the lung remained about 30 per cent collapsed. Right upper lobe tuberculosis was first present in 1945. In July, 1945, a right pneumothorax was begun and maintained until July, 1947, at which time a thickened pleura developed along with fluid. This lung remained about 40 per cent collapsed. Aspiration was carried out repeatedly on both sides and ultimately there developed a bilateral tuberculous empyema.

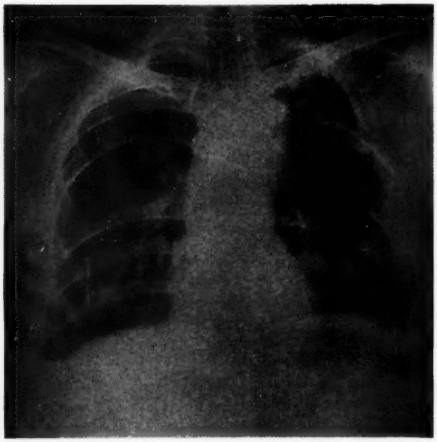
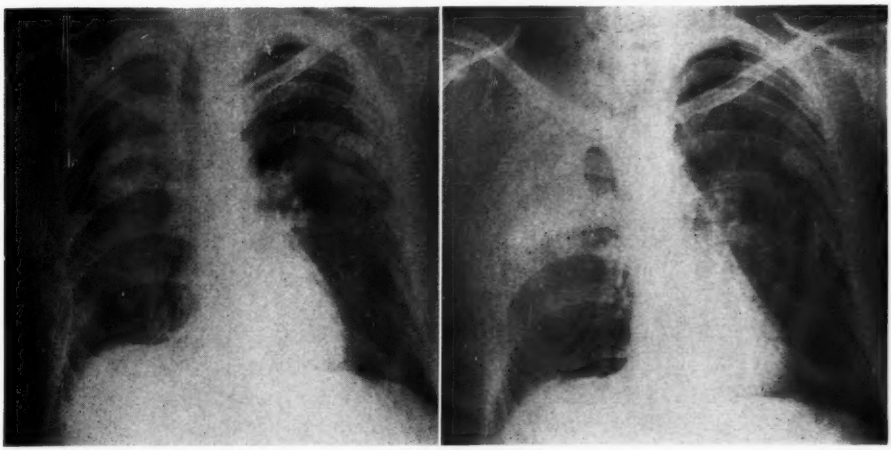


Fig. 3*E*.—After simultaneous left decortication and left thoracoplasty; function much improved; sputum, negative.

Sputum, however, converted by concentration in August, 1947, and by culture in April, 1948. During the years dyspnea developed and the patient became a respiratory cripple. Anxiety attacks periodically would result in the need for oxygen administration. Bilateral decortication was discussed with this patient and he was anxious to take the involved risks. The right side had had the least amount of tuberculosis and it was therefore decided to start on this side, to restore as much pulmonary function as early as possible. Therefore, on May 31, 1949, right parietal and visceral decortication was carried out. Re-expansion was not prompt, but ultimately the pleural space was obliterated and this was associated with marked clinical improvement. The patient was now able to stroll in the corridor and anxiety completely disappeared. On Feb. 21, 1950, left parietal and visceral decortication was carried out. Upon the completion of this, it was noted that with maximum re-expansion the left lung would not completely fill the pleural space. Therefore an apical thoracoplasty was done at the same time, and again the patient recovered uneventfully. After a few months of modified bed rest, activities were increased and he is now ambulatory and is anticipating his discharge from the hospital. Sputum has remained negative except for a rare positive culture.

This is another case of extensive original disease successfully controlled by pneumothorax for which thoracoplasty combined with decortication was necessary on the left to prevent reactivation and to insure obliteration of pleural space. It is also of unusual interest in that it represents bilateral pneumothorax complicated by bilateral empyema resulting in a respiratory



A. *B.*

C.

Fig. 4.—*A*, Unexpandable right lung with tuberculous empyema. Cavity patent in the right upper lobe, and sputum positive. *B*, After preliminary tailoring thoracoplasty. *C*, After right upper lobectomy and right middle and right lower lobe decortication; sputum, negative.

cripple. The combination of left thoracoplasty and bilateral decortication has changed a previously hopeless situation to one where the patient is now contemplating gainful employment.

CASE 4 (Fig. 4 *A*, *B* and *C*.).—G. H., a 35-year-old man, a hoisting engineer, developed cough and sputum in 1948. Chest roentgenograph in July, 1948, disclosed cavitary tuberculosis on the right, and positive sputum was found. He was therefore hospitalized, and a right pneumothorax was begun in August, 1948, but was complicated by pleuropulmonary adhesions. In December, 1948, a complete closed pneumonolysis was performed. This was complicated by fluid development which persisted and was positive for tubercle bacilli. The upper lobe became almost 100 per cent collapsed. Because of these complicating factors, re-expansion was attempted, but was attended by reopening of the cavity in August, 1949. Finally in December, 1949, an upper stage of thoracoplasty on the right was done. On Jan. 24, 1950, the right middle and lower lobes were decorticated, and the right upper lobe was excised. Except for one isolated culture, this patient's sputum has been negative by all methods since February, 1950. The spheroidal lesions in the contralateral lung have remained unchanged and stable. Block resection of these lesions was under consideration, but, because of disciplinary reasons, this patient was discharged from the hospital in July, 1950, and since that date has been working full time, is asymptomatic, and continues to be sputum negative by all methods.

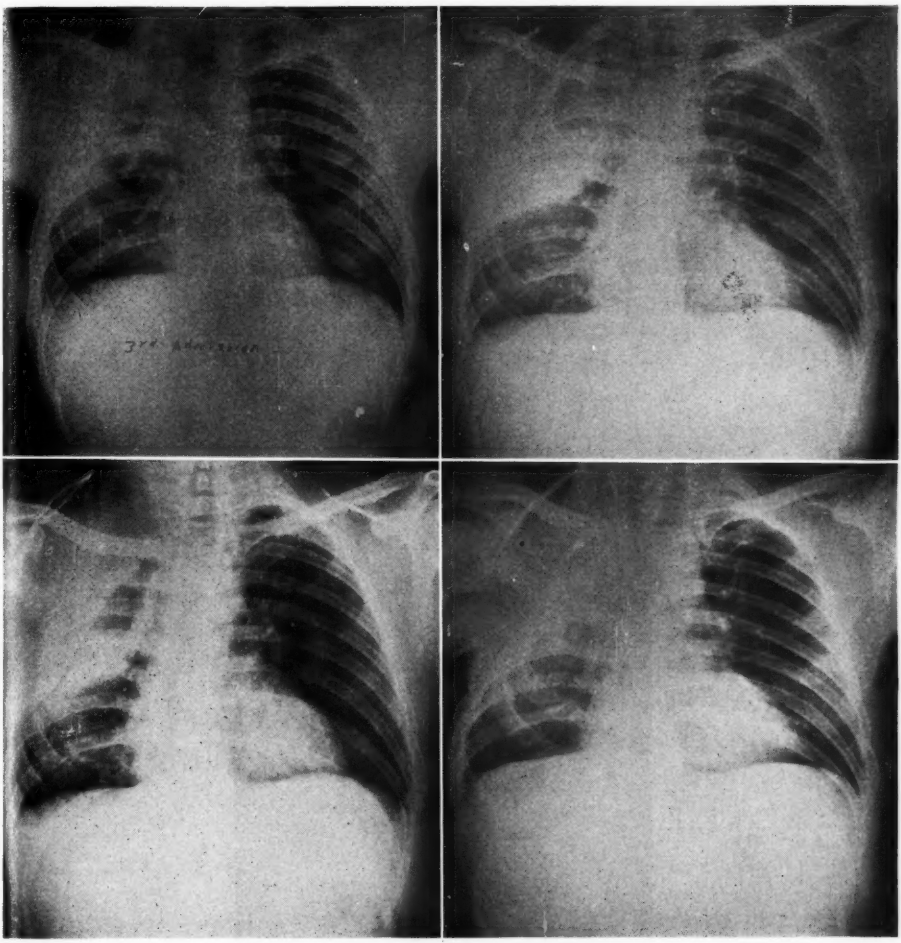
Here, despite adequate anatomical collapse by pneumothorax, parenchymal disease was uncontrolled, with patent cavity in the right upper lobe and smear positive sputum. This was further complicated by unexpandable lung and tuberculous empyema. Sputum conversion followed right upper lobectomy and decortication of the right middle and right lower lobes preceded by a tailoring thoracoplasty.

CASE 5 (Fig. 5 *A*, *B*, *C* and *D*.).—E. L., a 36-year-old foundry worker, first developed symptoms of pulmonary and spinal tuberculosis in 1930, but a diagnosis was not established until April, 1932. He was treated by bed rest, and an extrapleural pneumothorax on the right was performed Nov. 18, 1938. Following this he was admitted to a tuberculosis sanatorium in March, 1939, with a right extrapleural tuberculous empyema. This was treated conservatively by aspirations. Finally the area became opaque by roentgenograph, his sputum became negative, and he was discharged in September, 1941, as arrested. Also during this hospitalization a spine fusion was done, and his spinal disease was considered arrested. In December, 1942, he was readmitted because of a positive sputum and air and fluid in the extrapleural pocket. A broncho-extrapleural fistula was demonstrated by dye instillation and expectoration. By October, 1949, the space had again filled almost completely, but a small area of radiolucence still existed. From that time until the time of operation the scant sputum was negative for tubercle bacilli by concentration and culture. The left lung had been stable since 1945. Bronchoscopy on Jan. 17, 1950, revealed a normal tracheobronchial tree. As a preliminary procedure to right upper lobectomy and decortication of the extrapleural empyema sac, an upper stage tailoring thoracoplasty was performed on Jan. 19, 1950. Following this the broncho-extrapleural fistula reopened, and there was marked sputum production up to 14 ounces daily, positive for tubercle bacilli. Sputum production slowly decreased and the decortication and upper lobectomy were performed on Feb. 26, 1950. The postoperative course was completely uneventful, sputum immediately converted, and has been negative by concentration and culture to date.

This is a case of extrapleural pneumothorax complicated by extrapleural tuberculous empyema and a broncho-extrapleural fistula. Decortication of the

extrapleural empyema sac, resection of the right upper lobe and associated fistula preceded by a tailoring thoracoplasty was definitive therapy.

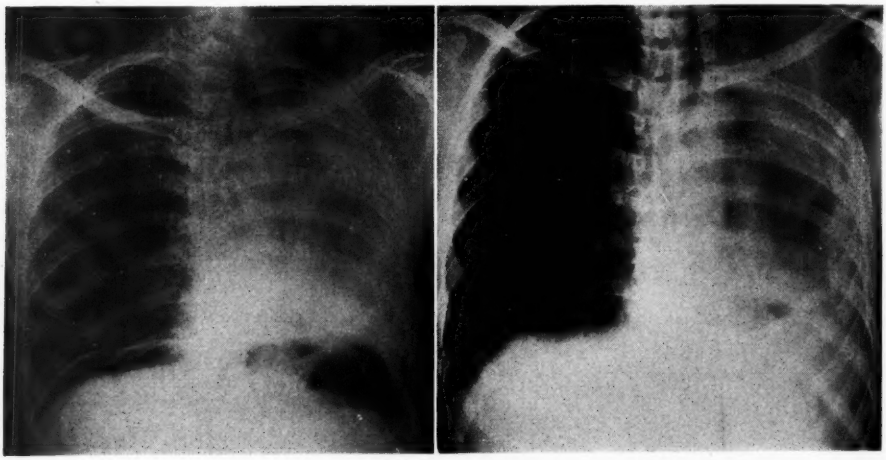
CASE 6 (Fig. 6 *A*, *B* and *C*.).—C. W., a 48-year-old Negro laborer, whose tuberculosis was diagnosed in January, 1947. The tuberculosis was progressive, and in July, 1947, a left pneumothorax was induced, but was complicated by pleuropulmonary adhesions. Re-expansion was started in July, 1948, but was never complete, and a purulent tuberculous pleural effusion developed. This was repeatedly aspirated from 1948 until the time of



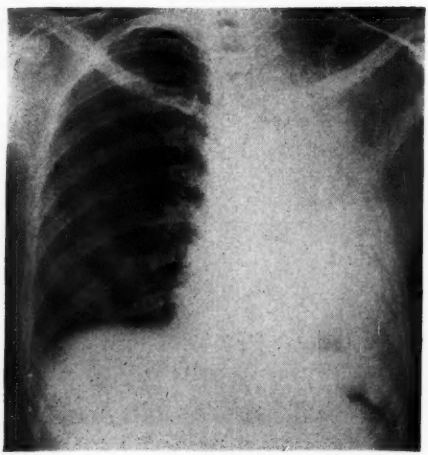
A. *B.* *C.* *D.*

Fig. 5.—*A*, Right extrapleural pneumothorax, tuberculous empyema and right upper lobe broncho-extrapleural fistula; sputum, positive. *B*, Fistula closed and sputum negative temporarily. *C*, After tailoring thoracoplasty, fistula reopened and sputum positive. *D*, After decortication of extrapleural empyema and right upper lobectomy; sputum, negative.

surgery. Pneumonectomy was anticipated, but pre-empyema films were not complete enough to present a clear picture of the extent of involvement in the left lung. Therefore, it was decided to do a preliminary tailoring thoracoplasty to be followed by thoracotomy when decortication and pulmonary resection would be done. The extent of pulmonary resection would depend upon the amount of involvement found at operation. The preliminary thoracoplasty was done on Aug. 9, 1950, pneumonectomy and excision of empyema sac on Sept. 12, 1950, and a final stage of thoracoplasty on Oct. 19, 1950. Contralateral lung has remained stable throughout this procedure, sputum is now negative by all methods including culture, and he is on increasing activity.



A. *B.*



C.

Fig. 6.—*A*, Extensive left lung tuberculosis with tuberculous empyema and unexpandable lung. *B*, After preliminary tailoring thoracoplasty. *C*, After left pneumonectomy, decortication of the empyema and a final stage of thoracoplasty; sputum, negative.

This represents the surgical program in a case with tuberculous empyema and uncontrolled parenchymal disease, the extent of which is difficult to determine by review of serial roentgenographs. Had a lobectomy and decortication been sufficient the surgical treatment would have been completed since preliminary tailoring thoracoplasty had been done. The finding of a destroyed lung required pneumonectomy and excision of the empyema. Obliteration of the pleural space was accomplished by a final stage of thoracoplasty.

CASE 7.—The case with complications of wound infection and residual empyema is a 39-year-old woman with total tuberculous empyema, cavitary tuberculosis of the left upper lobe, and endobronchial tuberculosis of the left lower lobe. She was known to have a bleeding tendency as demonstrated by the development of subcutaneous hematomas following needle aspirations and profuse bleeding during preliminary tailoring thoracoplasty. No cause of this hemorrhagic tendency could be determined. Despite this, the extensive tuberculous empyema demanded treatment. Decortication and pneumonectomy were started, but blood loss was so severe that operation had to be stopped after mobilization of the parietal portion of the empyema sac. The wound was packed, drained, and closed. Five days later the procedure was completed without difficulty. Despite completion of the thoracoplasty and pleural drainage, a small residual tuberculous empyema and moderate wound infection persists but is subsiding. The rarity of complications thus far in this series has been gratifying.

TABLE III A. RESULTS OF TREATMENT

Total number of cases		14
I. Successful pneumothorax—Decortication without resection		6
A. Without tailoring thoracoplasty	3	
B. With tailoring thoracoplasty	3	
II. Unsuccessful pneumothorax—Decortication with resection and tailoring thoracoplasty		6
A. Lobectomy	2	
B. Pneumonectomy	4	
III. Tuberculous pleurisy with effusion (spontaneous)		2
A. Unexpanded lung	1	
B. Empyema	1	

TABLE III B. RESULTS OF TREATMENT

Complications	
I. Wound infections	1
II. Reactivation or spread	0
III. Reversion of sputum	0
IV. Failure of re-expansion	0
V. Recurrence of empyema	1
Mortality	0

CONCLUSION

The mere demonstration of the presence of an unexpandable lung in the candidates for decortication is not a sufficient criterion for surgery. A thorough understanding of the natural history of pulmonary tuberculosis and a knowledge of the extent and activity of the existing disease are necessary as well as surgical skill. The finding of a positive sputum, even on culture only, becomes signifi-

cant in planning the surgical program. The source of the bacilli should be determined if possible and then thoracoplasty and/or resection should be done in conjunction with decortication. Thus in the total group of cases presented for decortication the parenchymal status must be evaluated. For the cases with moderate prepneumothorax disease, complete re-expansion by simple decortication is desirable and adequate. In that group with more advanced parenchymal involvement permanent collapse of the diseased area is required. This is accomplished by preliminary tailoring thoracoplasty and then decortication of uninvolved lung. Finally, those cases unsuccessfully treated by pneumothorax, with persistent active disease and positive sputum, require resection and simultaneous decortication. Where more than segmental resection is done, preliminary tailoring thoracoplasty is also indicated to prevent overdistention of remaining lung and to insure obliteration of pleural space.

SUMMARY

The problem of the unexpandable lung after therapeutic pneumothorax and its complications is discussed.

A review of the surgical treatments of the unexpandable lung is presented.

Pathology of the unexpandable lung is briefly referred to.

The indications for decortication are discussed in detail. A reclassification of indications based on the status of the underlying lung as well as the pleural pathology is presented.

Concepts of treatment based on these indications are discussed. These include combinations of decortication, thoracoplasty and pulmonary resection.

A series of fourteen cases is reviewed and illustrative examples are presented.

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DECORTICATION PRECEDING THORACOPLASTY FOR THE ELIMINATION OF LONG-STANDING TUBERCULOUS EMPYEMA*

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THE elimination of chronic tuberculous empyema secondarily infected or not is a problem at any stage. The more long standing the empyema, the greater the problem. Granted that prevention is the best treatment, some cases are bound to occur, though possibly less frequently with improved management in general.

Early treatment by conservative methods may eliminate some empyemas, and early surgery will cure others. The long-standing cases with which we are mainly concerned are generally conceded to be amenable only to surgery. The generally accepted method has been by extensive thoracoplasty. This succeeds in some, but a high percentage, over half according to Cuthbert, results in residual basal empyema and chronic sinuses, even after the Shede type of procedures. It may be noted that Cuthbert states that half of these long-standing cases are not fit for any surgery, and this writer quotes a mortality of 50 per cent. It is appropriate also to draw attention to the high morbidity and prolonged treatment with multiple operations so common in this condition.

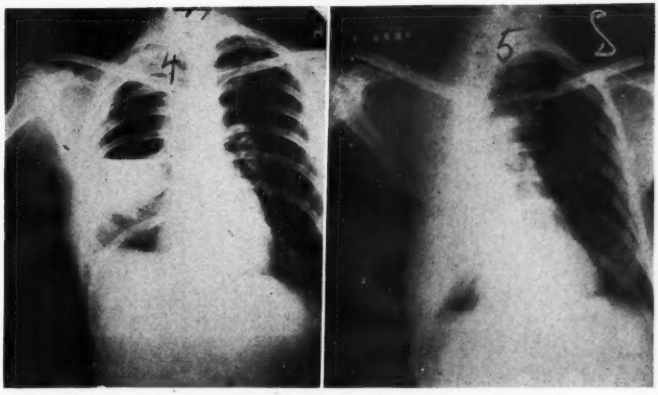
The decortication of chronic tuberculous empyema following thoracoplasty was practiced and discussed by the late Fraser B. Gurd before this Society in 1946. Subsequent contributions by Gordon and Welles, Weinberg and Davis, Mulvihill and Klopstock, and others have demonstrated that not only is this post-thoracoplasty decortication practicable, but that it could sometimes be carried out primarily and might even occasionally obviate thoracoplasty.

In reviewing our results with thoracoplasty in chronic empyema, it was noted that, other things being equal, surgery was most successful where the lower lobe had been well held out over the diaphragm by adhesions, and was only partially collapsed. In such cases (Fig. 1 *A*) a limited thoracoplasty combined with aspiration was generally adequate in achieving a cure of the empyema, leaving no sinuses or residual gutter pocket (Fig. 1 *B*). Such success was rarely the case with more complete lung collapse, when more extensive thoracoplasties regularly left draining sinuses from residual gutter empyemas (Fig. 2 *A*, 2 *B*, and 2 *C*). This regularly called for the mutilating Schede type of procedure with, all too frequently, further unsatisfactory results (Fig. 3 *A*, 3 *B*, and 3 *C*).

From Grace Dart Home Hospital, Royal Edward Laurentian Hospital and Queen Mary Veterans' Hospital.

Read at the Thirty-first Annual Meeting of The American Association for Thoracic Surgery, Atlantic City, N. J., April 16-18, 1951.

The satisfactory results in cases with the partially collapsed lung led us to attempt to imitate the natural intrathoracic conditions found in these cases in empyemas with more completely collapsed lung. This expansion was to be accomplished by a limited or lower lobe decortication followed by suction and later by aspiration. In other words, the plan was designed to coax the lower lobe out over the diaphragm where it could become adherent before thoracoplasty, whether the lung functioned or not. Thoracoplasty was to follow as soon as possible. This plan at the worst would preclude residual gutter empyema (Fig. 4 *A*), and ordinarily it would limit the subsequent thoracoplasty (Fig. 4 *B*), while at best it might make this operation unnecessary (Fig. 4 *C*). In Fig. 4 *A* a bronchogram indicates how even a relatively functionless lung can be made to suit the purpose of the plan as in Case 2, P. R. Fig. 4 *B* shows the limited thoracoplasty required in the same case, while Fig. 4 *C* illustrates the type of case in which subsequent thoracoplasty is not required.



A. *B.*

Fig. 1.—*A*, Chronic empyema following pneumothorax and pneumonolysis with partially collapsed right lower lobe naturally adherent well out over whole diaphragm despite exudate. *B*, Same case on discharge two months after completion of an eight-rib thoracoplasty, with only a brief aspiration period. Note absence of empyema. (Five-year follow-up shows patient healthy and working.)

It was early recognized that failure might result from certain pre-existing conditions, notably a bronchopleural fistula, extreme bronchial stenosis, or complete intrapulmonary fibrosis. These matters were given appropriate investigation in the cases encountered. It will be noted that only one of our patients had such a large fistula, and this case has so far been considered a failure. One patient had bronchial stenosis and was rejected. Several of the patients had extensive fibrosis, but this did not appear to defeat our purpose. These cases will be commented upon individually. We have thus perhaps been fortunate in our series, since at the outset no special selection was made, and most of the patients had been in and out of the hospital for many months, and the longest one six years.

The risk of expanding extensively diseased lobes has also been considered. After previewing all available old roentgenograms, none of our present series was considered as having too much involvement to be excluded from trial operation. However, such cases will be met with and each one must be dealt with on its merits. We have recently rejected two such candidates.

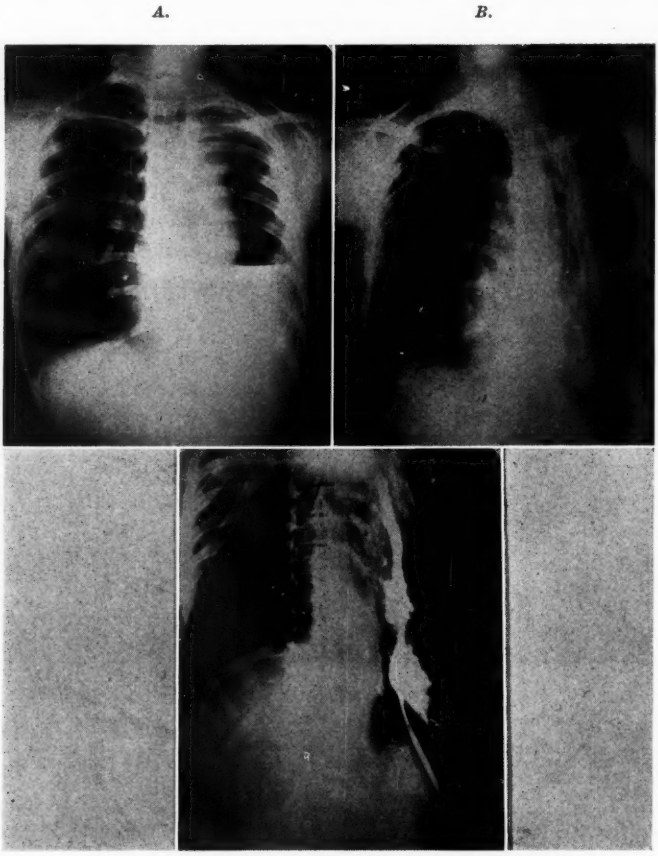


Fig. 2.—*A*, Chronic empyema following pneumothorax and pneumonolysis, with almost totally collapsed lung, nonadherent to the diaphragm, and showing some exudate. *B*, Same case three months after a standard nine-rib thoracoplasty showing residual gutter empyema and draining sinus. C, The residual cavity contains over 200 c.c. of Lipiodal.

The matter of functional restoration, or gain, in the expanded lung after decortication, has naturally also been investigated, though more or less a secondary consideration. It will be seen that the functional recovery varies widely in the individual case. Actually our results range from nil to 50 per cent normal, and are discussed individually. Functional recovery is of secondary

interest to us in this paper, however, since we have been concerned primarily with the obliteration of, or prevention of, the almost inevitable residual gutter empyema and its disappointing sequelae, even following the Schede type of procedure.

Fig. 3.—*A*, A case similar to that in Fig. 2. *B*, Same residual cavity six months after standard thoracoplasty. *C*, Following Shede operation, the gutter had finally dried up but only after two years.

Reports of ten cases are summarized and the results charted. It will be seen that a satisfactory and fairly rapid cure of empyema was effected in nine, and one has been a failure.

CASE REPORTS

CASE 1.—P. R., man, aged 27 years, G.D.H.H. No. 4073. Disease was discovered as minimal in both apices in 1943, and the patient was admitted to a sanatorium. Right pneumothorax was begun in November, 1944. He left the sanatorium in September, 1945, and returned in June, 1946. Left pneumothorax was indicated and begun at once. Pneumonolysis was necessary, and this was shortly followed by effusion. Emypema was diagnosed later that year (1946) and was treated by aspiration and a long course of streptomycin. The patient was admitted to Grace Dart Home Hospital in June, 1948.

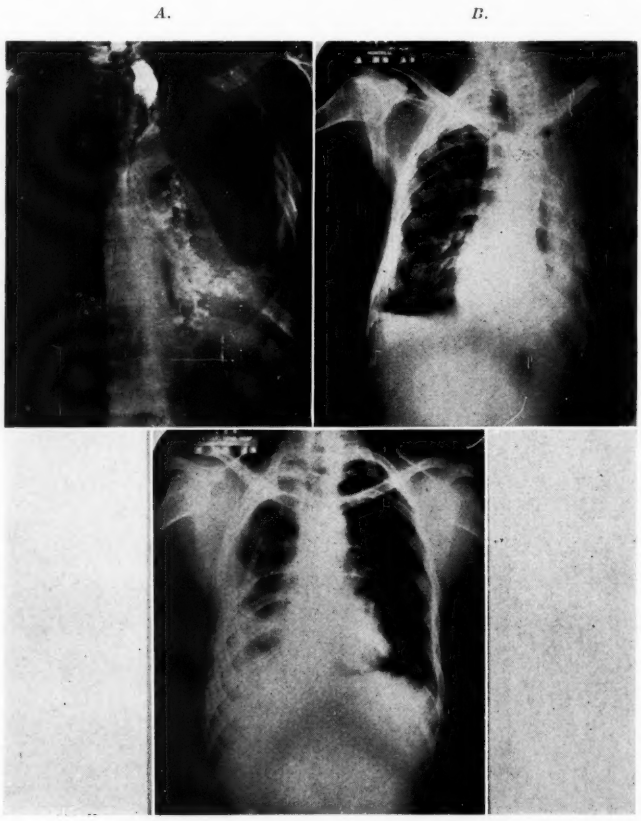


Fig. 4.—*A*, Bronchogram of the functionless left lung in Case 2, J. R., shows how even this type may be coaxed out to become adherent to diaphragm and serve our purpose. *B*, Following seven-rib thoracoplasty. *C*, Illustrates how decortication may even eliminate the necessity for thoracoplasty.

On examination the patient was febrile; sputum negative; weight 87 pounds. Chronic mixed left empyema with multiple draining aspiration sinuses. Pleural fluid showed acid-fast bacilli. The right side was considered stable. The blood picture was within relatively normal limits. The vital capacity was 1.2 liters. Bronchoscopy was negative. Bronchospirometry was attempted three times with unreliable results. There was no definite evidence of bronchopleural fistula.

On Feb. 1, 1949, decortication of the left lower lobe, lingula, and diaphragm was done with facility. Expansion of the lobe occurred with positive pressure on the table. Suction drainage with one 45F. tube was carried on for six days. Then the drain was removed and the wound sutured. Aspiration was continued, and the lower lobe remained well out on the diaphragm. Bronchospirometry showed minimal lung function (10 per cent). On March 29 a first-stage thoracoplasty was done, followed by second stage on May 10. Seven ribs in all

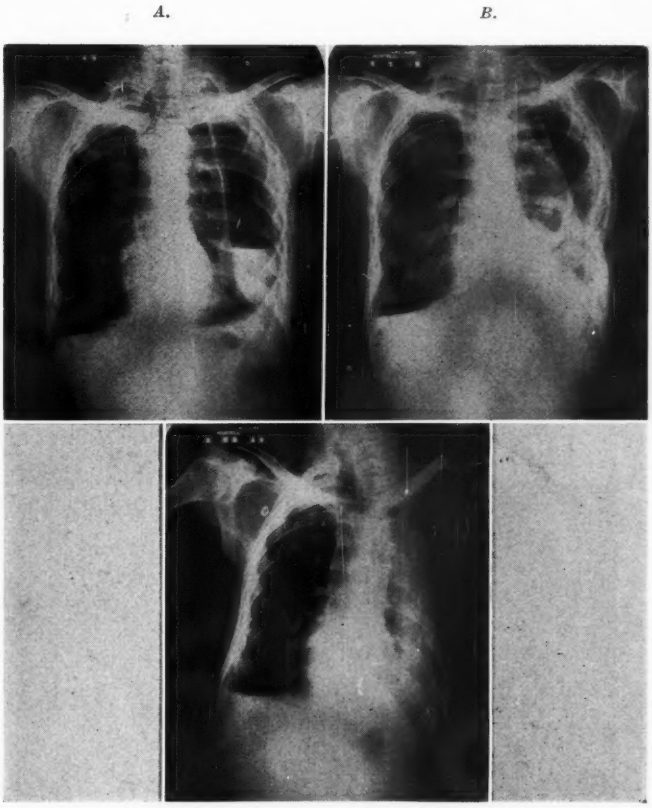


Fig. 5.—*A*, Case 1, P. R., showing collapsed lung in long-standing three and one-half year tuberculous empyema. Note thickened pleura. *B*, Expanded decorticated lower lobe before thoracoplasty. *C*, Postthoracoplasty result. There is a very minimal functional recovery.

were removed. The lung remained partly expanded. All aspiration ceased early in June because it became unnecessary. He was discharged on Sept. 16, 1949, weighing 95 pounds. The sputum has remained negative.

Follow-up in October, 1950: patient well and working (Figs. 5*A*, 5*B*, and 5*C*).

CASE 2.—J. R., man, aged 24 years, G.D.H.H. No. 4809. Disease was discovered in 1944, following repeated hemoptyses. Admitted to sanatorium, and a left-sided cavitary lesion was diagnosed. Pneumothorax was begun early in 1943, and was followed shortly by pneumonolysis. The pneumothorax was abandoned in 1943 because of effusion. Empyema was diag-

nosed in 1944. He was self discharged in 1946. He was readmitted to a sanatorium in February, 1948, and transferred to the Grace Dart Home Hospital the same month, and streptomycin treatment was added to aspiration.

On examination the patient was febrile. There was a left-sided chronic tuberculous empyema with a positive culture. There was a small tuberculous puncture abscess of the left axilla. The right chest was considered stable. Sputum was negative; weight 92 pounds; the

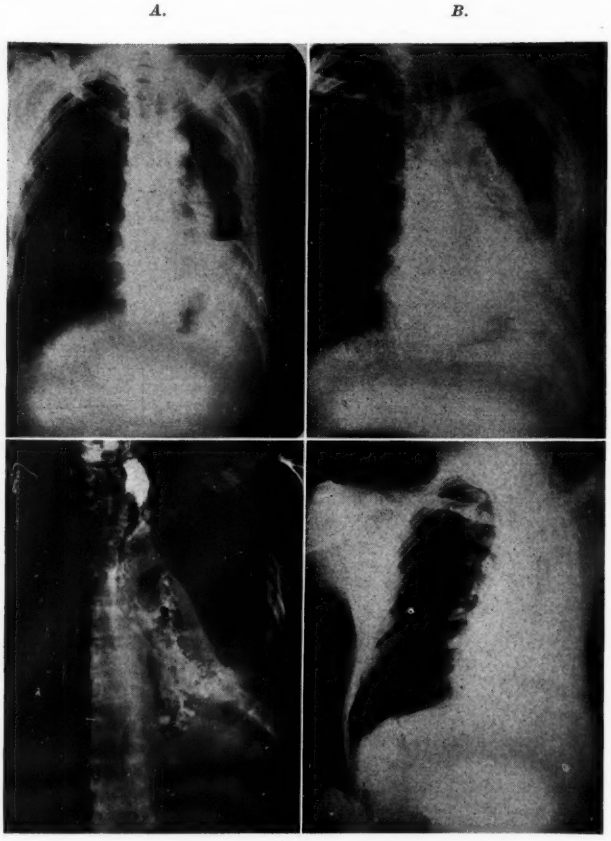


Fig. 6.—*A*, Case 2, J. R., shows collapsed lung in a six-year tuberculous empyema. *B*, Extent of expansion after decortication with minimal functional recovery. *C*, Bronchogram of same case showing how the lung has crept out over the diaphragm. *D*, Final result with minimal function.

blood picture showed moderate anemia; the vital capacity was 1.9 liters. Bronchoscopy showed early bronchitis in the left upper lobe bronchus. Bronchospirometry showed no oxygenation from the left lung. There was no definite evidence of a bronchopleural fistula.

On March 11 an incision and drainage of the axillary abscess was done. On March 16 decortication of the left lower lobe, lingula, and diaphragm was carried out quite easily. The lung did not expand under positive pressure on the table. Drainage of the left chest by

one 45F. tube with suction was continued for one week. Then the tube was withdrawn and the wound sutured. Aspiration was continued. The fibrosed lung remained well out over the diaphragm, as is well shown by bronchogram roentgenogram. On April 4, a bronchospirometry was done, showing no oxygenation of the left lung. On April 20 and 30 a limited seven-rib two-stage thoracoplasty was carried out. Aspiration ceased in May. He was discharged from the hospital to home on July 5, 1949.

Follow-up in October, 1950, found the sputum negative and the patient well and working (Figs. 6*A*, 6*B*, 6*C*, and 6*D*).

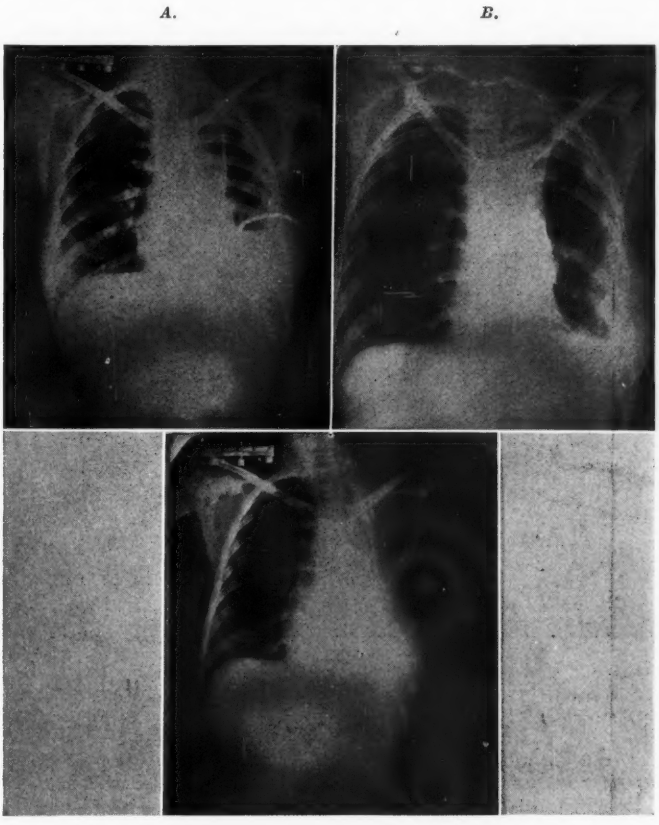


Fig. 7.—*A*, Case 3, T. N., shows collapsed lung with drainage tube. *B*, Functionless lower lobe just filling the gutter area. *C*, Final result after thoracoplasty.

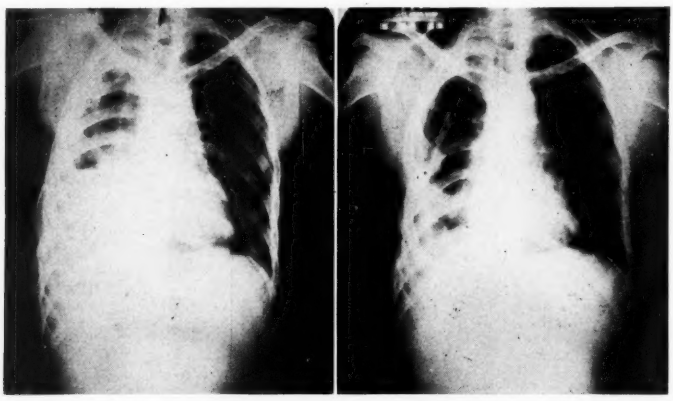
Case 3.—T. N., woman, aged 31 years, G.D.H.H. No. 4994. Disease was first recognized in 1943. She entered a sanatorium in 1944, where the left lung was found to have a cavitary lesion. Left pneumothorax was begun at once and continued for two and one-half years. It was abandoned because of effusion in 1946. At that time the right side showed some infiltration. In 1948 she was discharged home because her sputum was negative. She

was readmitted to sanatorium with empyema in October, 1949, and treated by aspiration and streptomycin. In February, 1950, she was transferred to the Grace Dart Home Hospital for surgery, with a drainage tube in her left chest.

On examination the patient was febrile; weight 90 pounds. She showed bilateral pulmonary tuberculosis, and the right lung was considered to be stable. There was a left-sided total empyema which contained Staphylococci and *B. coli,* but was negative for tubercle bacilli. There was a small drainage tube in situ. She had a small amount of negative sputum. The blood picture showed moderate anemia. The vital capacity was 1.1 liters. Bronchoscopy was negative. Bronchospirometry was unsatisfactory. There was no definite gross bronchopleural fistula.

On March 7, 1950, decortication of the left lower lobe, lingula, and diaphragm, and the lower parietal pleura was done. The lung expanded only slightly under positive pressure on the operating table. Drainage with appropriate suction by two 45F. tubes was carried on for six days, and then the wounds were sutured. Aspiration was continued. The lung remained partly expanded and adherent to the diaphragm. On April 5 and 25, a limited seven-rib two-stage thoracoplasty was done. Aspiration ceased in May. She was discharged on Oct. 6, 1950, when her weight was 96 pounds.

Follow-up in February, 1951, showed the patient at home and well (Figs. 7*A*, 7*B*, 7*C*, and 7*D*).



A. *B.*

Fig. 8.—*A*, Case 4, L. P., shows the empyema with only partial collapse of stable lung. *B*, Final result of decortication, requiring no thoracoplasty and rendering a 30 per cent lung function.

CASE 4.—L. P., man, aged 27 years, G.D.H.H. No. 4771. Disease was discovered in July, 1946, following pleurisy with effusion on the right side. He was admitted to a sanatorium in 1946, then discharged home. He was readmitted to a sanatorium in 1947 for thoracotomy with tube drainage for chronic empyema of mixed type. He was then transferred to the Grace Dart Home Hospital in September, 1948.

On examination he was febrile. The left lung was clear. The right side showed a chronic empyema with small draining sinus in the lower axilla. The upper lobe was partly expanded and functioning. Cultures from empyema showed *M. tuberculosis,* Staphylococci, and other organisms. His weight was 110 pounds. The vital capacity was 1.3 liters. Bronchoscopy was negative. Bronchospirometry showed 20 per cent function on the affected side. There wes no evidence of bronchopleural fistula.

On Jan. 11, 1949, decortication of the right lower and part of the upper and middle lobes was carried out. Suction drainage was continued for five days with a 45F. tube. Drainage

wound was then sutured and aspiration continued. The lung which had never been completely collapsed re-expanded under aspiration, and showed no active disease. Thoracoplasty was not done. Intermittent aspiration of a localized pocket of thin serum, negative for organisms, was continued until March. Bronchospirometry in August, 1949, showed increased function of the right lung estimated to be 30 per cent. He was discharged on Oct. 17, 1949. His weight at this time was 115 pounds.

In October, 1950, he was seen at the Clinic. He was well and working (Figs. 8*A* and 8*B*).

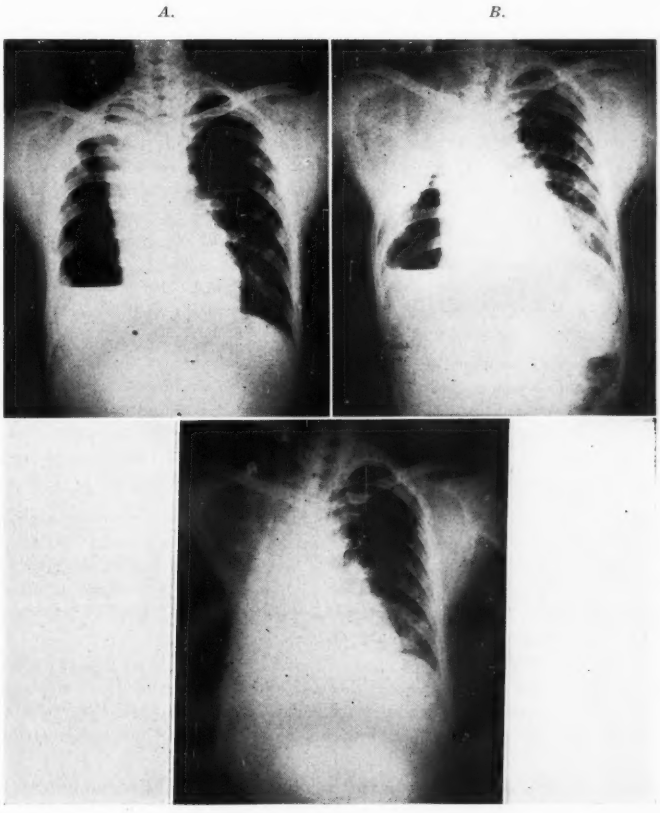


Fig. 9.—*A*, Case 5, R. D., shows empyema with total lung collapse. *B*, Condition following two-stage six-rib thoracoplasty. *C*, Result following completion of thoracoplasty and simultaneous decortication.

CASE 5.—R. D., man, aged 26 years, G.D.H.H. No. 4969. The disease was recognized in October, 1948. The patient was admitted to a sanatorium in October. He developed a right-sided spontaneous pneumothorax in January, 1949. Effusion followed almost at once, and this after six months gradually became purulent. He was transferred to the Grace Dart Home Hospital on Dec. 7, 1949, for surgery after nine months' treatment by aspiration and streptomycin.

On examination he was febrile. Roentgenogram revealed far-advanced bilateral disease. He had positive sputum. The empyema contents revealed a mixed infection. A two-stage six-rib thoracoplasty was done in February and March, 1950. A residual gutter empyema cavity remained. Small bronchopleural fistula was suspected.

On March 29 a third-stage thoracoplasty was performed removing ribs 7, 8, and 9; and decortication of the residual empyema and freeing of the diaphragm was done. There was minimal expansion of the lobe on the operating table. Drainage was accomplished through the eighth rib bed with a 45F. suction tube and carried on for six days, and then closed and followed by aspiration. This was followed by a phrenic crush on the right. Aspiration was no longer necessary after May, and he was then discharged to a sanatorium the same month.

He is now well and working (Figs. 9*A*, 9*B*, and 9*C*).

CASE 6.—A. M., man, aged 20 years, R.E.L.H. The disease was first recognized in January, 1948, as a cavitary lesion of the left upper lobe and infiltration of the lower lobe. The patient was admitted to a sanatorium, and a left pneumothorax was begun in April, 1948. He had a pneumonolysis in July, 1948, and again in January, 1949. This was followed by an effusion which was treated by aspiration. Tubercle bacilli were found in the effusion in September, 1949. He was transferred to the Royal Edward Laurentian Hospital for Surgery in November, 1949.

On examination the patient was febrile, with a negative sputum. There was a left-sided chronic tuberculous empyema with a positive culture. The right lung showed infiltration but was stable. There was no bronchopleural fistula. Bronchoscopy was negative. Bronchospirometry showed 80 per cent of function on the right and 20 per cent on the left side. The vital capacity was 3.2 liters.

On Jan. 30, 1950, decortication of the left lower and part of the upper lobe was done. Expansion on the table was immediate and good. Suction drainage was done for five days, and then the wound was sutured. The lung continued to expand and radiologically was stable enough so that thoracoplasty was not done. He was returned to the sanatorium after six months and has remained there since. The functional recovery of the expanded lung has been estimated by bronchospirometry to be 50 per cent (Figs. 10*A*, 10*B*, and 10*C*).

CASE 7.—D. M., man, aged 51 years, R.E.L.H. The disease was first recognized in January, 1950, and the patient was admitted to a sanatorium with a positive sputum. Pneumothorax was begun in April. In May, 1950, a spontaneous pneumothorax occurred following a refill. Effusion followed shortly and was treated by aspiration and streptomycin. In June, 1950, the tubercle bacilli were found in the thickening effusion. He was transferred to the Royal Edward Laurentian Hospital for surgery.

Examination on admission showed the patient to be febrile, and a positive sputum. In the background there was infiltration of both lungs with an upper cavitary lesion on the right. His weight was 140 pounds; vital capacity 2.6 liters; bronchoscopy showed atelectasis but no stenosis. There was no evidence of a bronchopleural fistula. Bronchospirometry was not done.

On June 12 a lower lobe decortication was done with good expansion on the table under positive pressure. Within a week suction drainage was discontinued, and the wound was closed. Aspiration was continued. In September and October he had a two-stage seven-rib thoracoplasty done, which cured the empyema and converted him.

He is presently in the sanatorium and remains well.

CASE 8.—G. D., man, aged 25 years, Q.M.V.H. The disease was found in June, 1948, and he was admitted to a sanatorium where a left pneumothorax was induced. In December, 1948, effusion became prominent, and six months later *M. tuberculosis* were found. He was treated by aspiration and streptomycin without success. He was transferred to the Queen Mary Veterans' Hospital in October, 1949.

Examination on admission showed the patient to be febrile. The sputum was negative. He had a left-sided tuberculous empyema. The contralateral side was clear. Bronchoscopy

was negative. No bronchopleural fistula was present. The vital capacity was 1.6 liters. Bronchospirometry on the left was 1 per cent.

In December, 1949, lower lobe decortication was done with immediate expansion, and this was shortly followed by a two-stage seven-rib thoracoplasty. The subsequent course was uneventful, and after one year he is well in the sanatorium.

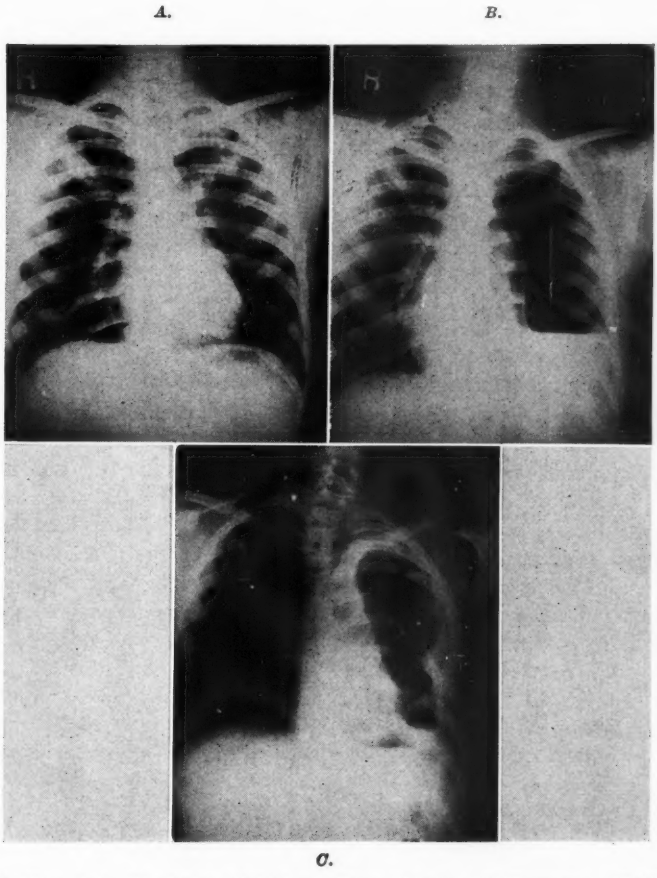


Fig. 10.—*A*, Case 6, A. M., shows original condition of lungs. *B*, Empyema. *C*, Stable, expanded lung with 50 per cent functional recovery requiring no thoracoplasty.

CASE 9.—I. L., man, aged 35 years, Q.M.V.H. The onset of disease was in 1947, when he was admitted to a sanatorium where a right pneumothorax was shortly begun. The effusion became empyema in 1948, and he received conservative treatment for the next year. In 1949 he was transferred to the Queen Mary Veterans' Hospital for surgery.

On admission the patient was febrile, and had a positive sputum. There was a right-sided tuberculous empyema and the contralateral side showed infiltration. Bronchoscopy showed no definite bronchial disease, and the bronchopleural fistula was only recognized later. Vital capacity was 2 liters.

TABLE I. ANALYSIS OF CASES

CASE NO.	1-P.R.	2-T.R.	3-T.N.	4-L.P.	5-R.D.	6-A.M.	7-D.M.	8-G.D.	9-I.L.	10-G.B.
Type of empyema	mixed	Tbc.	mixed	mixed	mixed	Tbc.	mixed	Tbc.	Tbc.	Tbc.
Condition underlying lung originally	upper cavity	upper cavity lower infilt.	upper cavity	infilt. all zones	extens. cavity	upper cavity	upper cavity lower infilt.	upper cavity	upper cavity	upper infilt.
Contralateral lung	stable	clear	stable	clear	stable	infilt.	stable	stable	infilt.	stable
Sputum	neg.	neg.	neg.	neg.	pos.	neg.	pos.	neg.	pos.	neg.
Bronchopleural fistula	0	0	0	0	+	0	0	0	+	0
Bronchoscopy	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.	pos.	neg.
Vital capacity	1.2 L.	1.9 L.	1.1 L.	1.3 L.	2.2 L.	3.2 L.	2.6 L.	1.6 L.	2 L.	3 L.
Bronchospirometry	unrel.	no func.	unrel.	20%	not done	20%	not done	1%	not done	not done
Extent of fibrosis	++	+++	++++	+	+++	+	++	++++	++++	+
Age	27	24	31	27	26	20	51	25	35	37
Sex	M	M	F	M	M	M	M	M	M	F

TABLE II. ANALYSIS OF CASES

CASE NO.	1-P.R.	2-J.R.	3-T.N.	4-L.P.	5-R.D.	6-A.M.	7-D.M.	8-G.D.	9-I.L.	10-G.B.
Extent of decortication	L.L.L.	L.L.L.	L.L.L.	R.L.L. & MID.	R.L.L.	L.L.L. PT.UPP.	R.L.L.	L.L.L.	R.L.L.	R.L.L. MID.
Expansion of lung	immed. partial	min.	immed. partial	immed. good	min.	immed. good	immed. good	immed. good	min.	immed. good
Extent of thoracoplasty	7 ribs	7 ribs	7 ribs	none	9 ribs	none	7 ribs	7 ribs	8 ribs	none
Functional recovery	min. 10%	nil.	min.	30% of normal	nil.	50% of normal	min.	min. 1-5%	nil.	fair
Period effusion to empyema	6 mo.	18 mo.	18 mo.	1 yr.	9 mo.	1 yr.	2 mo.	6 mo.	1 yr.	6 mo.
Length conservative treatment	2½ yr.	4½ yr.	6 mo.	3 yr.	9 mo.	1 yr.	2 mo.	1 yr.	1 yr.	6 mo.
Total pre-op. time	3 yr.	6 yr.	2 yr.	4 yr.	18 mo.	2 yr.	4 mo.	18 mo.	2 yr.	1 yr.
Period oper. to discharge	6 mo.	3 mo.	6 mo.	9 mo.	3 mo.	3 mo.	3 mo.	3 mo.	not disch.	6 mo.
Follow-up	18 mo.	2 yr.	1 yr.	2 yr.	1 yr.	1 yr.	9 mo.	1 yr.	1 yr.	2 yr.
Result	satisfactory	satisfactory	satisfactory	satisfactory	satisfactory convert.	satisfactory	satisfactory convert.	satisfactory	failure	satisfactory

In June, 1949, lower lobe decortication was carried out with moderate expansion. Shortly after the operation the newly expanded lung collapsed, however. The empyema became secondarily infected, and the bronchopleural fistula was recognized. Thoracoplasty was done in three stages, but the patient has a persistent gutter cavity of mixed empyema and chronic sinus.

CASE 10.—G. B., woman, aged 37 years, Q.M.V.H. The patient's disease was found in 1948, and she received a right pneumothorax in the sanatorium. Effusion developed shortly afterward and this became recognizable empyema in May, 1949. For the next six months conservative measures were adhered to, then she was transferred to the Queen Mary Veterans' Hospital for surgery.

Examination on admission showed that the patient was febrile, and she had a negative sputum. There was right-sided tuberculous empyema and minimal areas of stable infiltration in the opposite lung. Bronchoscopy was negative, and there was no bronchopleural fistula. Vital capacity was 3 liters.

In September, 1949, decortication of the right lung was done with immediate good expansion. No thoracoplasty was needed as the underlying expanded lung was stabilized. The functional recovery has been only fair, however, but not accurately estimated.

COMMENT

Although the technique used and management following operation are now generally known and need not be recounted, a few comments are indicated.

Generally speaking, the visceral peel has been developed and removed with no great difficulty, leaving islands wherever very adherent to underlying visceral pleura or lung. In only two cases was the visceral peel so densely adherent as to make removal tedious, and these were cases with extensive pulmonary fibrosis. The diaphragm has been freed and some respiratory movement obtained in each instance, otherwise the amount of parietal decortication has been variable, and tended to be minimal. The upper lobe has been partly decorticated in three instances where more complete expansion was anticipated and considered desirable. In these instances considerable functional lung was restored and thoracoplasty obviated. Tears in the visceral pleura, where appreciable, have been sutured at once to minimize air escape. This has been variable and on the whole not remarkable. Fibrin foam has been used at times. Using endotracheal anesthesia, positive pressure expansion of the decorticated lung has been attempted in every instance with varying results, as shown on the summary chart. When expansion has occurred it has not been subsequently lost except in the one failure. Postoperative suction drainage has been accomplished with one 45F. tube and maintained for not more than a week in any case. The suction pressure varied from 10 to 20 cm. of water. After removal the drainage wounds were deliberately sutured, and aspiration substituted. Persistent sinus tracts occurred in our one failure. The aspirated fluid has never become purulent in any case but the failure. Streptomycin and sulfonamides have been used topically.

In Case 5 thoracoplasty was begun before the decortication which was carried out actually at the third stage. The variation in procedure was adopted in an effort to offset the existing bronchopleural fistula. Though successful, it was found technically more difficult than operation upon the uncollapsed thorax. In this case a phrenic crush was added, but not in the others.

Our results so far have been encouragingly successful, as will be seen from the preceding case reports given with minimal detail. For easier study we have added charts embodying the principal data. It may be noted that there have been no deaths, and morbidity has been remarkably light. As a result of this, the plan is calculated to cut the patient's hospitalization notably.

We wish to emphasize the time element in these results—most of the patients have been lying around sanatoria or hospitals for years.

SUMMARY

1. The unsatisfactory and mutilating results of the past surgery for chronic tuberculous empyema, including Schede type of operations, has engendered the plan to decorticate before thoracoplasty. This plan is particularly useful for the more completely collapsed lung, and decortication should include at least the lower lobe and diaphragm. More extensive visceral and parietal clearing should be done as indicated.

2. This plan was suggested by the observation that in those chronic empyemas with the lower lobe adherent to the diaphragm, a limited thoracoplasty is generally successful in preventing residual gutter empyema and draining sinuses.

3. The results of the plan have been generally satisfactory in our small series, even when the empyema was as long standing as six years. By satisfactory we simply mean the elimination of the empyema.

4. This result is our prime consideration and may occur with or without more or less functional improvement in the collapsed lung. Such a gain in function has occurred in some cases and was well marked in two. This accrued benefit makes the decortication plan the more valuable.

5. The fairly rapid recovery and early discharge from hospital, even in very long-standing cases, are facts which may well be stressed.

6. There have been no deaths in our series, and morbidity following operation has not been noteworthy.

7. Our one failure had an appreciable bronchopleural fistula. This may be considered as a possible contraindication, at least in the large ones, though we would like more experience. It is possible that means may be found to circumvent this difficulty.

8. Another more definite contraindication is underlying active pulmonary disease forbidding lung expansion.

9. Extensive pulmonary fibrosis is not a contraindication, since functional recovery is not a prime consideration, as has been demonstrated.

10. This argument may also apply to bronchial stenosis, though it is by no means clear.

11. Most of our successful cases have been followed for well over a year with satisfactory results.

12. The successful application of decortication procedures before, during, and after thoracoplasty gives hope that these procedures will largely eliminate the more mutilating operations.

13. Finally, a plea should be made for not delaying the surgery once the empyema is established. This plea is underlined by the greater likelihood of achieving maximum functional recovery, even making thoracoplasty unnecessary in a fair percentage of cases.

Of the ten cases included in this report five are from the Grace Dart Home Hospital, two from the Royal Edward Laurentian Hospital, and three from The Queen Mary Veteran's Hospital, all of Montreal. We are indebted to Dr. C. A. MacIntosh for permission to include his case reports, also to Dr. E. A. MacNaughton for his interest and slides.

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DISCUSSION ON "SIMULTANEOUS DECORTICATION AND RESECTION IN UNSUCCESSFUL PNEUMOTHORAX," BY DR. ARNOLD O. RILEY AND DR. VICTOR H. KAUNITZ; AND "DECORTICATION PRECEDING THORACOPLASTY FOR THE ELIMINATION OF LONG-STANDING TUBERCULOUS EMPYEMA," BY DR. F. DOUGLAS ACKMAN, AND DR. PATRICK MADORE.

DR. DAVID H. WATERMAN, Knoxville, Tenn.—We are indebted to Dr. Riley and Dr. Kaunitz, and to Dr. Ackman as well. Essentially, the indications for decortication given by Dr. Riley and Dr. Kaunitz are in agreement with ours, and are those that the Committee on Surgical Therapy of the American College of Chest Physicians, of which I was a member and Dr. Abbott was chairman, presented at San Francisco last year. Certainly the indications are widening, as you can well see.

As to the group that requires resection, I think it might be mentioned that by and large those patients having extensive disease, and thus not suitable for decortication, have probably been poorly selected for pneumothorax in the first place. When we do resections on such patients we are, in essence, substituting the correct therapy that should have been applied in the first place. On the other hand, the case that has been well selected for pneumothorax will probably be ideal for decortication.

As to surgical procedure, we are in entire agreement that the parietal peel should be removed in all cases. We disagree, however, in the resection of the rib. We feel that

an intercostal incision in decortication, even when the ribs are almost overlapped, is quite feasible with the use of the Inge bone spreader, an instrument we mentioned in a recent publication. With this instrument the ribs can be spread apart, the intercostal space divided accurately, and the parietal peel stripped away before it is incised. Then with the use of an ordinary rib spreader, gradually tightened, an adequate exposure can be obtained without division of any ribs whatever. For several years we have advocated this incision for all intrathoracic work, in fact, and we think that postoperative function of the chest wall is far better if there is minimal interference with both musculature and rib cage.

DR. KAUNITZ, (closing): Dr. Riley and I want to thank the Association very much for the privilege of addressing this meeting.

For the reasons Dr. Chamberlain gave earlier this morning, we have felt that thoracoplasty as a preliminary procedure should be done in a separate stage. We realize that other surgeons are using the same procedures we have indicated, but we felt that it was worth while to describe what we consider a logical method of handling these somewhat complicated situations.

SUBSCAPULAR PARAFFIN PACK AS A SUPPLEMENT TO THORACOPLASTY IN THE TREATMENT OF PULMONARY TUBERCULOSIS

W. E. Adams, M.D.,* William M. Lees, M.D.,** and James M. Fritz, M.D.* (by invitation)
Chicago, Ill.

THE modern type of paravertebral thoracoplasty is the operation of choice in a large percentage of patients with pulmonary tuberculosis where surgical therapy is indicated. This operation has withstood the test of time and yields a high percentage of satisfactory results. Concomitantly, when it is carried out in an adequate number of stages, the risk of the procedure is minimal and the complications few.[1]

In spite of the contributions this procedure has made in the management of pulmonary tuberculosis, it has several disadvantages which leave room for improvement. Foremost among these is the fact that a significant percentage of patients are left with a persistently positive sputum.[2] Thus, further surgery is required either in the form of collapse or resection therapy. This means that the morbidity, as well as the risk of therapy, is increased. A second factor is the necessity for the employment of a multiple stage procedure in order to safeguard against paradoxical motion with spread of the disease to other parts of the lung. Of less importance is a third factor; i.e., the resultant deformity due to scoliosis and a sinking in of the scapula and subclavicular area.

All of these features must be considered when deciding in favor of therapy by thoracoplasty or by resection of the involved area. Although in recent years the mortality of operation and incidence of complications associated with the resection procedure have decreased considerably due to the use of chemotherapy, they still remain a deterrent factor in some types of lesions.

In an effort to improve the benefits of surgical collapse from time to time, a number of procedures have been employed with variable degrees of success. Some of these have been extrapleural in type, others have been subcostal interventions: Extrapleural pneumonolysis and pneumothorax (Tuffier[3]), with gauze pack (Schlange[4]), with fat (Tuffier[5]), with muscle (Alexander[6]), with rubber sheeting (Lilienthal[7]), with paraffin (Baer[8]) and with plastic material (Wilson[9]); supraperiosteal and subcostal pneumonolysis with rubber bag (Sherer[10]), gauze pack (Lilienthal[7]), muscle (Alexander[6]), paraffin (Eloesser[11]) and plastic material (Lucas[12]). When their employment has been restricted to specific types of lesions, some of these procedures have proved to be useful. However, unwarranted extension of their usage has often led to their discredit.

From the Department of Surgery of the University of Chicago, The Municipal Tuberculosis Sanatorium, Chicago, and the Stritch School of Medicine Department of Surgery of Loyola University.

Read at the Thirty-first Annual Meeting of The American Association for Thoracic Surgery, Atlantic City, N. J., April 16-18, 1951.

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**Department of Surgery, Loyola University.

The degree and selectivity of the collapse obtained by one of these methods; viz., extrapleural paraffin plombage, has been noteworthy. It was this observation that suggested the possible advantage of using a paraffin pack in combination with thoracoplasty.

OBJECT OF PROCEDURE

In the modern type of thoracoplasty, a serosanguineous fluid accumulates in the area of collapse following surgery. As this fluid is later absorbed, the underlying lung becomes partially re-expanded. This contributes to failure of healing of the underlying tuberculous lesion in a significant percentage of patients.

In the operation described below the space produced by the thoracoplasty is permanently obliterated by a molded piece of paraffin. This prevents re-expansion of the collapsed lung and produces a more selective type of collapse.

OPERATION

In 1947 when this procedure was first used, a two- or three-stage operation was made. Paraffin molded to fit the space produced by rib resection at the first stage was removed at the second or third stage and was not replaced. After it was found that the wax was well tolerated, it was left in place indefinitely. Furthermore, a better collapse was effected when the procedure was performed in one stage rather than in two or three stages. Since paradoxical movement was prevented by the snug fitting paraffin pack, the risk of spread of the infection was little more than in the two- or three-stage operation.

The operative procedure used at the present time (and for the last 50 cases) consists of a subperiosteal resection of the entire first and second ribs and as much of the third to the fifth, sixth or seventh ribs as indicated by the extent, location and nature of the underlying lesion. This is performed in one stage through an approach commonly employed for the conventional type of thoracoplasty. If the lesion requires more than a seven-rib thoracoplasty, the operation is performed in two stages, more paraffin being added at the second stage. Very little of the transverse processes of the vertebrae need be removed. Relaxation of the lung along the spine is increased by mobilization of the parietal pleura and division of the intercostal muscle bundles adjacent to the spine.

While the prepared paraffin is cooling, it is molded into one piece of a size and shape to fit the space produced by the collapse. The outer surface of the paraffin is rounded to fit into the hollow of the scapula and is flush with the outer surface of unresected ribs. No attempt is made to greatly increase the degree of the collapse by pressure.

The soft tissues of the chest wall are carefully approximated without drainage by a combination of continuous and interrupted sutures. During the immediate postoperative period a variable amount of fluid accumulates about the wax. If the amount is sufficient to cause distension of the tissues, it is removed by aspiration. This should be expected in at least 50 per cent of the operations and aspiration may need repeating.

ADVANTAGES OF THE PROCEDURE

The principal accomplishment of this operation is the production and maintenance of a more adequate collapse of a tuberculous lesion than is possible with the conventional type of thoracoplasty. This is possible due to the fact that the lung is prevented by the plomb from re-expanding as the subscapular fluid is absorbed.

Other advantages of somewhat lesser importance are: (1) a more selective type of collapse is obtained, usually associated with the resection of fewer ribs; thus, more functioning lung remains below the collapsed area, a factor of considerable importance in bilateral disease with decreased pulmonary reserve.

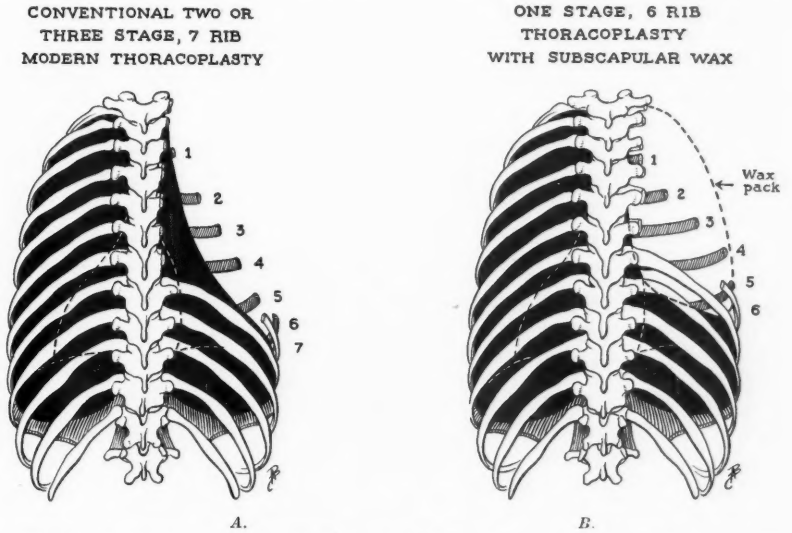


Fig. 1.—*A*, Diagrammatic illustrations of the bony thorax after a modern type, seven-rib thoracoplasty, *B*, following a six-rib, one-stage thoracoplasty with a subscapular wax pack. Note greater degree and selectivity of collapse in *B*, with resection of one less rib in one stage and without the removal of entire transverse processes.

(2) Good results may be obtained without the resection of the entire transverse processes; thus, little scoliosis develops following the procedure. (3) Since paradoxical motion is prevented by the immobile pack, a five- or seven-rib resection may be safely completed at one operation. Thus, the cost of therapy is decreased and the morbidity lowered. (4) The collapsed area is obliterated by the paraffin pack which thus prevents a sinking in of the scapula and subclavicular tissues. There is, therefore, little if any deformity following operation. Since this type of thoracoplasty has been used, there has been a noticeable willingness on the part of the patients to accept the operation.

COMPLICATIONS

Our experience has been with sixty-five patients treated over the past three and one-half years. Complications of the procedure have been infrequent and

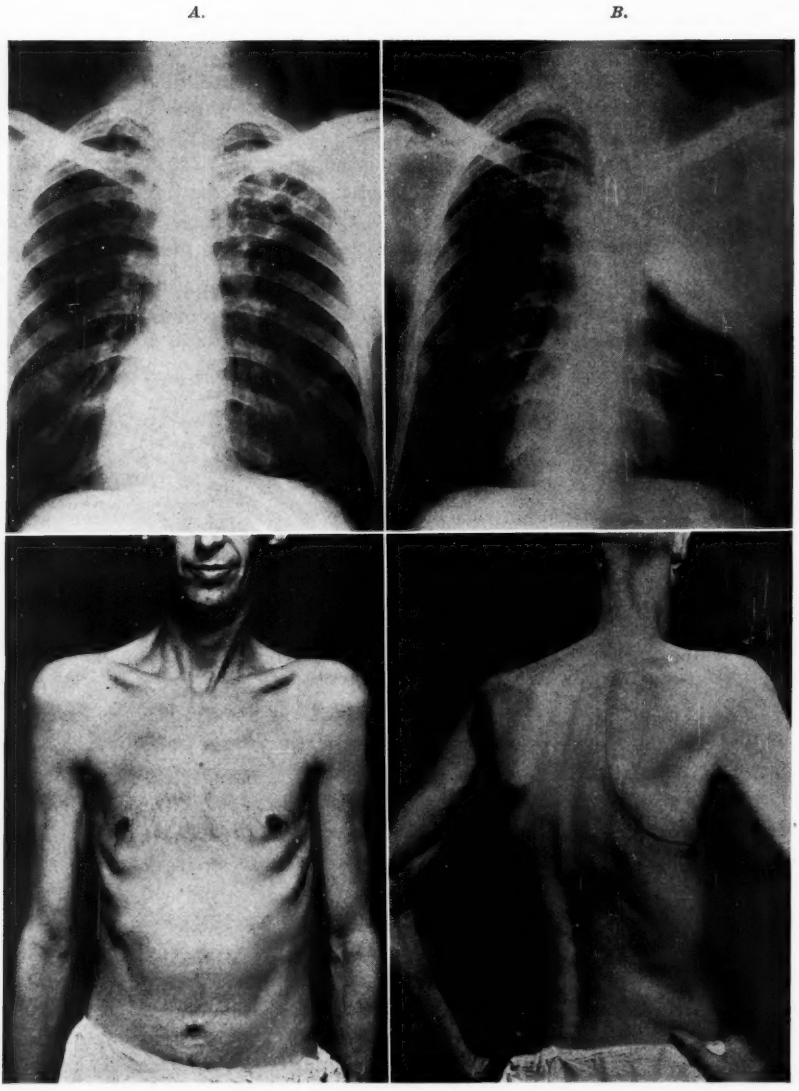


Fig. 2.—*A*, PA roentgenogram appearance of a 38-year-old white man showing multiple cavitation and infiltration extending from the apex to the level of the right second rib anteriorly. Scattered infiltrations are present in the left lung. *B*, Roentgenographic appearance following a six-rib, one-stage thoracoplasty with subscapular paraffin pack. Note selectivity and completeness of collapse with preservation of lung function below, *C* and *D*, the patient three weeks following operation. Note absence of scoliosis or other evidence of deformity.

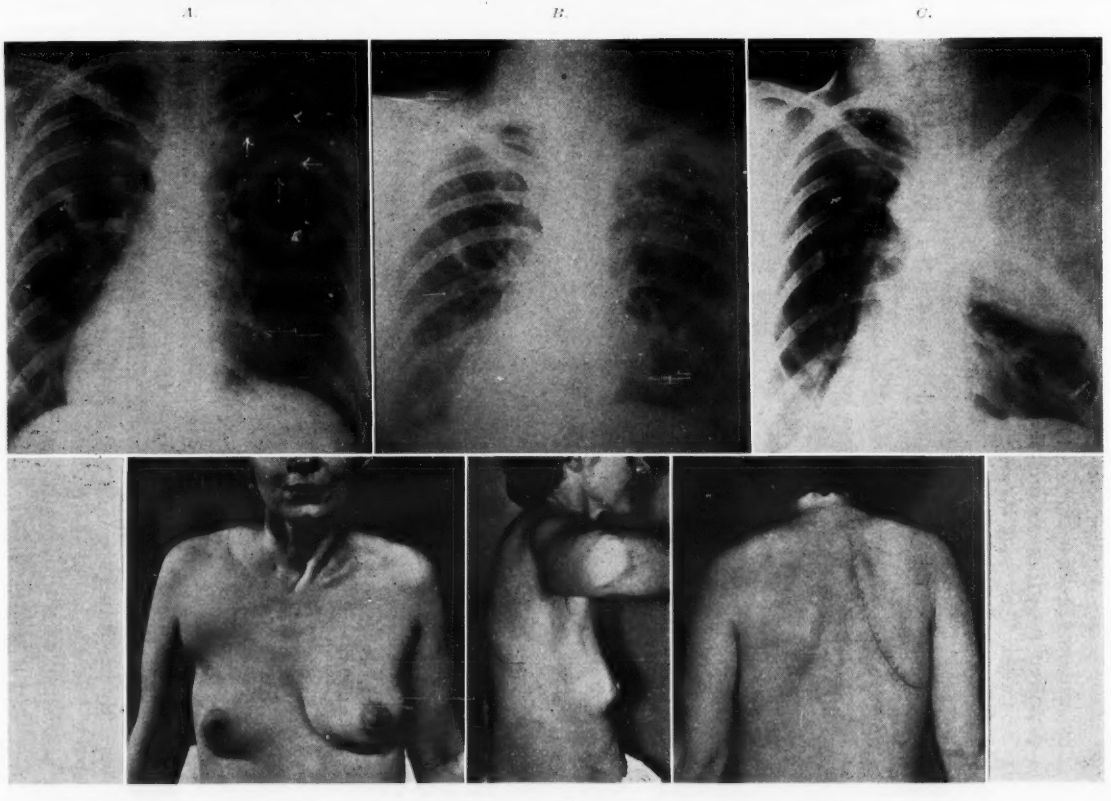
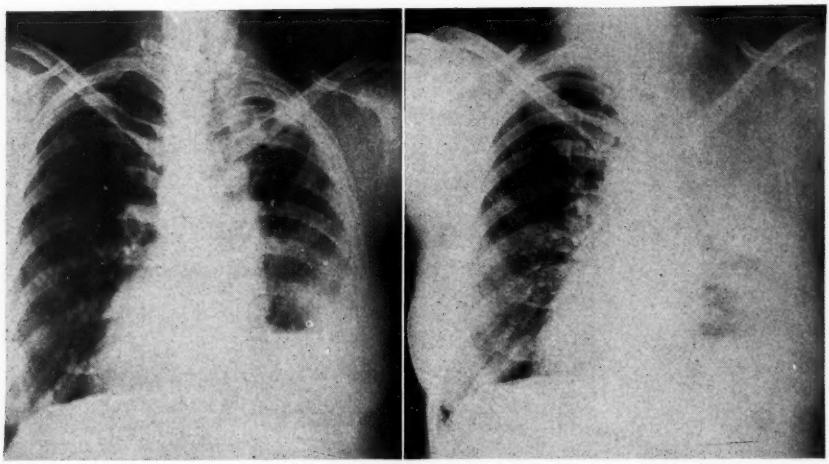


Fig. 3.—*A*, Roentgenographic appearance of chest of a 38-year-old white woman showing infiltration of the lung and two large cavities in the right apical and subapical areas. Note infiltration of left lung. *B*, Collapse by pneumothorax had been unsuccessful. *C*, Radiograph appearance following a seven-rib, one-stage thoracoplasty with subscapular paraffin pack. Note extension of selective collapse to a level somewhat below that of the resected ribs. *D*, *E*, and *F*, the patient following operation. Note little evidence of deformity.

were no different from those of the conventional type of thoracoplasty. There have been no infections of the subscapular space and no bronchial fistulas. Atelectasis has been seen in two patients, and in both instances disappeared following bronchoscopic aspiration. One superficial infection developed which healed readily without ill effect. In one patient, before aspiration of subscapular fluid was employed, opening of the wound with extrusion of a portion of the wax occurred. The wound subsequently healed spontaneously. There have been no deaths attributable to the use of subscapular wax. In 1947, one patient with far-advanced bilateral disease expired following the second stage of a two-stage thoracoplasty of cor pulmonale. In 1948 one patient died due to a transfusion reaction. There have been no late complications.



A. *B.*

Fig. 4.—*A*, Preoperative roentgenogram of a 39-year-old white woman showing moderate sized cavity in right subapical area. Incomplete aeration is present at right base following resorption of pleural effusion. Scattered infiltration is present in the left lung. *B*, Appearance following a six-rib, one-stage thoracoplasty and subscapular pack. Note completeness and selectivity of collapse.

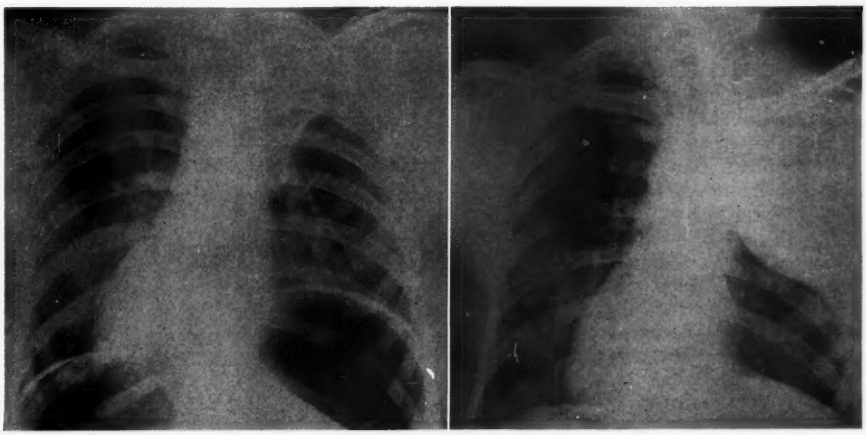
DISCUSSION

The rationale of this operation appears to be on a sound foundation. It combines the benefits obtained by both thoracoplasty and extrapleural plombage with paraffin, and simultaneously eliminates the undesirable effects or complications of each. By protecting the lung and maintaining the blood supply to the tissues through preservation of the periosteum and intercostal structures, complications associated with extrapleural paraffin pack are avoided. Since less pulmonary reserve is sacrificed and deformity is prevented, the deficiencies of the conventional type of thoracoplasty are eliminated.

In performing the operation several factors should be kept in mind. Resection of ribs below the second should not be carried forward to include the anterior ends since this may allow the paraffin to gravitate anteriorly out of

the proper position. Thus, an inferior degree of collapse would result. The amount of paraffin to be used should be of sufficient size to obliterate completely the area of collapse and maintain the scapula in normal position. This amount is usually 400 to 500 Gm. in a five- to six-rib thoracoplasty. Closure of the wound should be made with care since some pressure usually develops due to the accumulation of fluid. Closure in layers with a combination of interrupted and continuous sutures has been found satisfactory.

Indications for operation have been similar to those for modern thoracoplasty. It is possible that with further experience these indications may be extended. This is intended as a preliminary report since insufficient time has elapsed to know what may eventually be accomplished with the procedure. However, in most patients the sputum becomes negative within a few weeks after operation.



A. *B.*

Fig. 5.—*A*, Radiograph of a 28-year-old white man showing involvement of right upper lobe with retraction toward the apex. A pneumoperitoneum is present below. *B*, Postoperative view following a six-rib, one-stage thoracoplasty with subscapular pack. The pneumoperitoneum was largely obliterated before operation.

SUMMARY

The use of subscapular paraffin pack in thoracoplasty for pulmonary tuberculosis is described from an experience with sixty-five patients over the past three and one-half years. Its advantages over the conventional type of thoracoplasty include: (1) a better and more selective collapse; (2) reduction of expense and lower morbidity; (3) less reduction in pulmonary reserve; and (4) lack of postoperative deformity. Complications are no different than those associated with the conventional type of thoracoplasty.

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DISCUSSION

DR. ALFRED GOLDMAN, Beverly Hills, Calif.—Like Dr. Adams, we have been impressed with the possibilities of improving collapse therapy with extra-fascial packing or extra-periosteal packing. To do this, we have used plastic spheres in the extra-fascial space. The first group of patients, operated on beginning in the latter part of 1947, were those who had had concomitant removal of the upper three or four ribs.

(Slide.) This shows the reaction that occurs around the lucite spheres; it is made up largely of collagenous tissue; often the lining of this reaction is made up of low cuboidal epithelium.

(Slide.) This shows the extra-periosteal lucite pack with thoracoplasty of three ribs for closure of this cavity. This was one of the early patients who has been sputum-negative for three years.

(Slide.) Another patient, showing the cavity with the phrenic and thoracoplasty, and extrafascial lucite pack.

(Slide.) This young woman was operated on about two and a half years ago; nine months afterward she became pregnant; she was delivered without exacerbation after a normal confinement.

(Slide.) These are the results in the first fourteen cases of extrafascial lucite pack with thoracoplasty. One patient is positive, since this slide was made about eighteen months ago; two other patients have had lobectomy and one patient has expired from tuberculosis.

(Slide.) This shows the size of the cavities in which the operation was done. Most were more than two centimeters in diameter.

(Slide.) This shows the position and the technic used. Incision is almost the same as a thoracoplasty exposure.

Later we began a second type of extrafascial procedure in which we left the ribs in and put the lucite pack under the ribs.

(Slide.) This shows the lucite pack under the ribs.

Of the total number of patients who have had this type of operation, either with the ribs in or removed, there were 89, and of this number 69 or 78 per cent are sputum-negative on repeated culture at this time.

DR. EDWARD J. O'BRIEN, Detroit, Mich.—I really do not think there is much excuse for packs of any sort or embellishments of thoracoplasty. There is only one excuse for a paraffin pack, and that is because respiratory reserve is so low that nothing else could be tolerated. Here, a very small pack might be risked with proper fear of what might happen. Using these foreign bodies, whether lucite balls or snowballs or paraffin or whatever it is, reminds me of loaning money to a good friend. You expect to get it

back. You will get it back either through the bronchus or when you go back in to take it out. I still think that, in a cavernous lesion, a good thoracoplasty is preferable to resection for reasons that are obvious, I think—lower mortality, fewer complications, etc. By good thoracoplasty, I mean complete resection of all the transverse processes, including first, also the rib ends. The first three ribs should be removed to the cartilage; the remaining ones far forward, and a sufficient number of them removed to get well below the cavity. If, after a good clean thoracoplasty, without a lot of rubbish piled in, you still have positive sputum after about six months or more, a resection should be done. I think the tendency is to rush to resection too quickly, however, I do not think you can expect to take a thick leather-wall cavity, filled with exudate, and collapse it, and expect it to be closed and healed in a month or six weeks. I have seen cavities that were apparently open three or four months after thoracoplasty that would close later. I think some time limit must be set, and we have thrown six months in as the probable opportune time.

I would like Dr. Adams to explain to me just how he avoids pressure when one does not know just how much of a foreign body is needed to cause cavity closure. In one of his cases, I noticed that the lesions were productive. We believe that productive, caseous lesions that persist or recur after treatment should be resected, but the use of all forms of foreign body packs and embellishments of thoracoplasty should cease.

MR. W. P. CLELAND, London, England.—I would like to thank you very much for the opportunity of speaking before you, although I rather hesitate to take the floor after Dr. O'Brien's remarks about these procedures. On the other hand, I have come to the conclusion that my "friends" must be good ones, as most of my money has not been retruned to me either through the bronchus or by other routes.

My training in the treatment of tuberculosis evolved around the Semb type of thoracoplasty, and my own experiences with that procedure have been very satisfactory, with a cavity closure rate of approximately 80 per cent and a similar rate of sputum conversion. I was, however, a little unhappy with the procedure as it necessitated multiple stages, produced a certain amount of deformity and also left the apical portion of the lung unsupported and liable to develop paradoxical movement. I believe that paradoxical movement has a lot to do with the spread of the disease and atelectasis which occurs in a number of cases.

In order to overcome some of those deficiencies I started to experiment with various forms of plombage. I read with great interest the reports from this country about the early use of lucite balls but found them rather discouraging. I think a close study of thoracoplasties and extrapleurals gives a clue to the bad results obtained with the early plombage cases. Our own experience with extrapleural pneumothoraces indicates that sooner or later about 20 per cent of cases develop tuberculous pus in that extrapleural space. On the other hand the thoracoplasty rarely develops pus in the extrafascial space. This space is more remote from the lung and therefore from diseased lung tissue and this, I think, is a clue to the avoidance of many of the troubles that one has with plombage.

I employ a procedure very similar to the one that Dr. Goldman described, leaving all the ribs in situ but stripping them of their periosteum except for a small portion on the outer aspect. This allows the intercostal muscles with their blood supply to fall down with the mobilized lung, where they form a barrier between the plomb and the lung tissue. I divide the second and third ribs posteriorly so as to give plenty of space to do an apicolysis, which I believe is of value in achieving cavity closure. After mobilizing the lung the ribs are resutured, leaving solid chest wall which does not exhibit paradoxical movement. The plastic material we have been using recently is polythene made in 1.25 inch spheres; they are solid but they have a half-inch hole bored through the center. They are in fact really beads. They are not particularly heavy but they have this great advantage over the hollow lucite balls in that they can be boiled and one can be absolutely certain about their sterility. I have done in the last few years nearly 200 cases of this type, with complication rates which are approximately half of those en-

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countered with my own thoracoplasties; and with results as regards cavity closure and sputum conversion which I think compare favorably with the Semb type of thoracoplasty.

The whole crux of this plombage problem I am sure is going to rest upon the final attitude of the tissues to a foreign body, and in that connection I would like to mention that in these 200 cases I have had only three that have developed tuberculous pus late after the procedure. These are the only three cases that have given rise to any trouble directly referable to the plomb.

DR. T. R. HUDSON, Chicago, Ill.—Being situated geographically rather close to Dr. Adams, Dr. Head and I were stimulated early in his work and we have tried this procedure; altogether we have used it in forty cases. We have followed a somewhat different procedure, however, in that we ordinarily do not leave the paraffin permanently in place, removing it at the second stage of thoracoplasty. For one reason or another, however, in fifteen cases we did leave paraffin in place after the first stage of thoracoplasty. Four of these had to be removed because of unusual accumulations of fluid which could not be effectively dealt with by repeated thoracentesis. So far as complications are concerned we have had none in these forty cases, unless you consider a rather violent accumulation of fluid around the pack a complication. There have been no infections, no extrusion of paraffin, and no bronchopleural fistulae. I would like to show three or four slides:

(Slide.) This series of slides simply shows the lesion at the beginning.

(Slide.) This shows the paraffin pack in place, and the third slide shows the patient after the second stage of thoracoplasty and removal of the paraffin pack.

I think you will all agree that is a rather severe lesion shown in the first film, and probably a much better thoracoplasty with the pack than one would expect without having used it.

(Slide.) This is another patient; on the left the appearance of the chest after the second stage of thoracoplasty, the pack having been removed; it shows the large accumulation of fluid that does occur.

(Slide.) This shows the girl after an undetermined period, and shows, I believe, a rather good thoracoplasty and one which might be better than one would expect without the use of the pack.

(Slide.) This shows a girl with a very large cavity in the top of the left lung, in which we did two stages of thoracoplasty, using the pack between the stages. This lesion was so extensive that we felt something in addition was needed, so, following removal of the pack in the second stage we continued to keep this space by means of air injections into the subscapular space, and the second slide shows her condition during that course of treatment.

I might say that in removing all these packs we have noticed a very definite inflammatory membrane that forms around the pack, and I suppose it is this inflammatory membrane that contains the air and keeps it from extravasating into the fascial and muscular planes.

(Slide.) This is an example of a patient in whom we had thought we might leave the pack in, but as you see there was a terrific extravasation of fluid around the pack; the operation was done originally for a small lesion, and it was felt unjustified to leave the lung in this condition, so we removed the pack and continued the smaller refill space which does effectively control the lesion.

DR. ROBERT KLOPSTOCK, Jamaica, New York.—It is recognized that the most reliable form of cavity healing occurs by concentric shrinkage and not by compression and subsequent inspissation. We felt that the mechanism for this method of cavity closure could be achieved by providing a graded relaxation of the chest wall rather than by added compression of the diseased area. Performing the thoracoplasty in caudo-apical progression seems to provide the mechanism referred to.

The advantage of this procedure was brought to our attention by Drs. Herbert C. Maier and Walter Fischer who, in 1947, demonstrated a case with a giant cavity in which

the thoracoplasty was performed from below upward to prevent ipsilateral spread. We were so impressed with their result "as such" that we undertook caudo-apical thoracoplasty in a number of consecutive cases and studied the mechanism of cavity closure with interstage anteroposterior and lateral tomography. We found that the so-called lower or first stage (at a level as determined by the extent of the pathology) provides an immediate relaxation of the diseased area and an immediate concentric diminution in the size of the cavity. And at the time of the final or apical stage, it permits a concentric shrinkage of the cavity-bearing parenchyma rather than causing compression of the cavity itself and its subsequent inspissation. Our observation is based on 100 consecutive cases performed at Triboro and Seaton Hospitals by Morris Rubin and myself, on patients in whom resection was not desirable due to their borderline conditions or to the extent and distribution of their pathology. This procedure, as we used it, eliminated the need for supplementary procedures such as apicolysis, anterior stages, or revisions. The patients have been followed from one to four years since completion of their surgery.

(Slide.) These are roentgenograms of a typical case operated upon; the preoperative conventional chest radiogram, and left lateral tomogram. You see two very large cavities; one occupying the apico-posterior segment of the left upper lobe, one in the superior segment of the left lower lobe.

(Slide.) The Bucky film of the left chest shows that the posterolateral segments of the seventh and sixth ribs have been resected. You see on the two lateral tomograms that both cavities are markedly diminished in size by concentric shrinkage.

(Slide.) Again the Bucky film of the left chest: lower and middle stages have been completed and the upper three ribs not yet removed. The two lateral tomograms demonstrate a further considerable decrease in the size of the cavities.

(Slide.) This is the conventional roentgenogram of the chest after completion of the seven-rib thoracoplasty. The patient has been observed now for three years, having negative cultures.

We feel that such gratifying results in the presence of large cavities of the size as demonstrated could not have been achieved with a seven-rib thoracoplasty if developed in the conventional apico-caudal fashion.

DR. ADAMS, Chicago (closing).—I wish to thank the discussors for their remarks. I appreciate the fact that the reaction against using foreign bodies within the chest has been rather severe, and naturally one is influenced by his experiences which may have been unfavorable in the use of foreign material. This has been largely in connection with extrapleural paraffin pack or lucite plombage. I was acquainted with the experiences of the group at the Brompton Hospital, having talked with Dr. Lucas a short time ago when he visited this country. Others including Dr. Goldman, Dr. Head, and Dr. Meltzer, have used paraffin or plastic material placed outside of the intercostal muscles and periosteum beneath the scapula, with favorable results. The results, as time goes on, are likely to be different from those in cases where it was used extrapleurally. Of course, as I have said, this is in the form of a preliminary report and at a later date we can make a follow-up report.

ENDOSCOPIC SPONGE BIOPSY

M. G. Carter, M.D.* (by invitation), R. R. Nesbit, M.D.** (by invitation), and C. A. Piper, M.D.*** (by invitation)
New Haven, Conn.

RECENT improvements in both the instruments and technique of endoscopy and the introduction of methods for cytologic examination of sputum and bronchial secretions have reduced the number of patients with intrathoracic disease in whom a preoperative diagnosis cannot be made. We have used modifications of the Papanicalaou smear technique for identification of cells secured at bronchoscopy or esophagoscopy. There are certain limitations to the method, as others have noted.[1] Our principal troubles were inadequate specimens or smears which were too heavy, excessive amounts of pus or mucus, a predominance of blood in the slides, and dry specimens. There is no question that the pathologist must be interested in spending time and effort in the search for and interpretation of cells, which at times is a tiresome and difficult task. Even under the best circumstances, the limitations of this, and probably of any other cytologic method, prevent either the dogmatic assumption that positive smears always mean cancer, or more certainly, that negative smears prove its absence.[2]

Recently, we began using Gelfoam, and later Onkosponge† for collection of secretions endoscopically. This report summarizes the significant information from the first eighty patients in whom bronchoscopy and/or esophagoscopy were performed since we adopted this cytologic method.

METHOD

Sponge biopsies were obtained endoscopically by the method described by Gladstone.[3] They are secured at bronchoscopy as illustrated in Fig. 1. The bronchoscope is passed and, after a thorough examination of the bronchial tree, a small segment of sponge which has been securely fastened to the standard sponge carrier is introduced into the orifice of the suspected lobe or segment. This sometimes induces cough, which is probably a desirable effect, since it ejects material from the bronchus. The sponge is moved gently and is allowed to remain in contact with the secretions or mucosal surface for at least one minute. It is then withdrawn and immediately placed in a small bottle containing 10 per cent neutral formalin. If a visible tumor is present, the sponge may be rubbed vigorously over the tumor surface.

When investigating lesions of the esophagus or cardiac end of the stomach, the sponge is rubbed over the visible tumor or pushed through the strictured area. If cancer is thought to penetrate the wall of the trachea secondary to an esophageal lesion, the sponge is rubbed over the area suspected.

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Read at the Thirty-first Annual Meeting of The American Association for Thoracic Surgery, Atlantic City, N. J., April 16-18, 1951.
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†May be obtained from Histomed, Inc., Patterson, N. J.

When received by the pathology laboratory, the sponge is handled precisely as are tissue sections. After removal from the formalin it is carried through the fixing fluids, embedded in paraffin, and multiple sections are made which are placed serially on one or more slides. The paraffin blocks are preserved so that further sections may be cut if interpretation of the slides is equivocal.

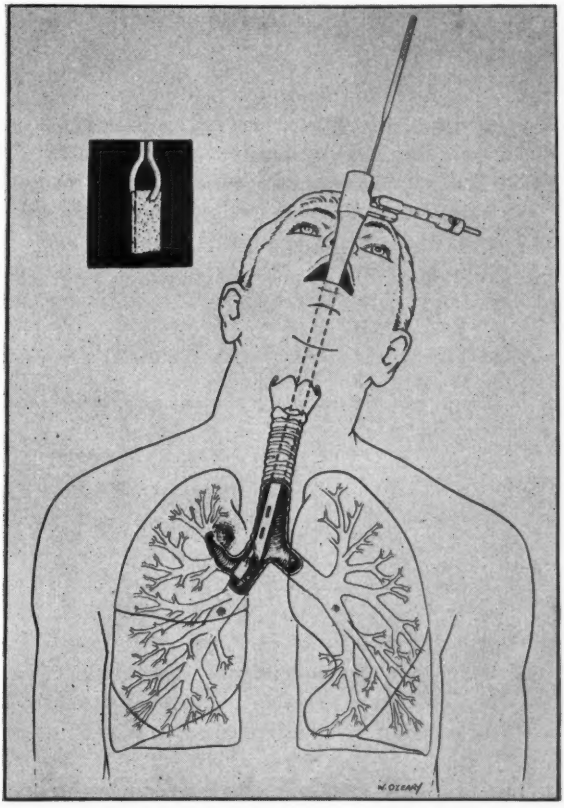

Fig. 1.—Drawing to illustrate the sponge biopsy method for obtaining tumor cells at bronchoscopy. Inset shows enlarged view of sponge in carrier.

MATERIAL AND RESULTS

The ages of the patients ranged from 20 to 81 years. Fifty-nine of the patients were over 50 years of age. There were sixty-five males and fifteen females.

Twenty-three patients were proved to have tumors of the lung of which twenty-two were cancer and one was adenoma. The diagnostic sequence for these patients is illustrated in Table I. Preliminary clinical diagnoses included carcinoma in twenty-one patients, lung abscess in one patient, and pneumonia in one patient. A positive diagnosis of cancer was established by bronchoscopy in

TABLE I. DIAGNOSTIC SEQUENCE IN TWENTY-THREE CASES OF PROVED PULMONARY TUMORS

DIAGNOSTIC METHODS	DIAGNOSES					
	ABSCESS	PNEUMONIA	CANCER	SUSPECTED CANCER	BENIGN TUMOR	NO TUMOR SEEN
Clinical	1	1	21			
Endoscopic	1		7	7		8
Sponge			7	6	1	9
Final diagnoses*			22		1	

*Established by operation or autopsy.

seven, suspected in eight, and bronchoscopy was negative in eight. In this same group, sponge biopsy was positive for cancer cells in seven and questionable in six. No tumor cells were seen in nine, and tumor cells "probably benign" were found in one. This last patient was subsequently shown to have a bronchial adenoma. The patients with a positive sponge biopsy were not all from the same group of seven as those showing a positive bronchoscopy. Tumor cells were identified in the sponge taken from two patients in whom tumors were not diagnosed by bronchoscopy. There were no falsely positive sponge biopsies.

TABLE II. DIAGNOSTIC SEQUENCE IN FOURTEEN PATIENTS WITH LESIONS OF THE ESOPHAGUS OR GASTRIC CARDIA

	CANCER OF ESOPHAGUS	CANCER INVADING TRACHEA	CANCER GASTRIC CARDIA ASCENDING	ESOPHAGEAL STRICTURE, BENIGN
Endoscopy diagnostic	9	1 (Fistula)	0	2(?)
Endoscopy not diagnostic	0	2	3	0
Sponge diagnostic	Not done	2	1 (Suggestive)	1 (Suggestive)
Total cases		9	3	2

Fourteen patients had lesions in the esophagus or cardiac end of the stomach (Table II). Nine of the esophageal lesions proved to be carcinoma, and in three of these the tumor had eroded into the trachea. Invasion of the trachea could not be confirmed with certainty by the bronchoscope alone, but sponge biopsies from the trachea of two patients revealed cancer cells. In one of the three patients with tracheal invasion a fistula was present and the sponge was unsatisfactory. The diagnosis of benign stricture of the lower end of the esophagus was made in three patients who later proved to have carcinoma of the gastric cardia. In one of these, cells suggesting carcinoma were present on the sponge; the sponge was negative in the other two.

Two patients with benign stricture of the lower one-third of the esophagus, secondary to peptic esophagitis, were also examined. In one of these, hyperkeratosis of the cells was noted.

Twenty-two patients had acute and chronic pulmonary inflammatory diseases. These included bronchiectasis, bronchitis, middle lobe syndrome, infaret, pneumonia, and lung abscess. In this entire group there was not a single sponge biopsy which was interpreted to show tumor cells (Table III).

Three patients had pulmonary tuberculosis. In two, this was parenchymal and in one there was tuberculous endobronchial ulceration. Endoscopic sponge biopsies showed pus cells, bacteria, and fungi, but no tumor cells. Acid-fast stains

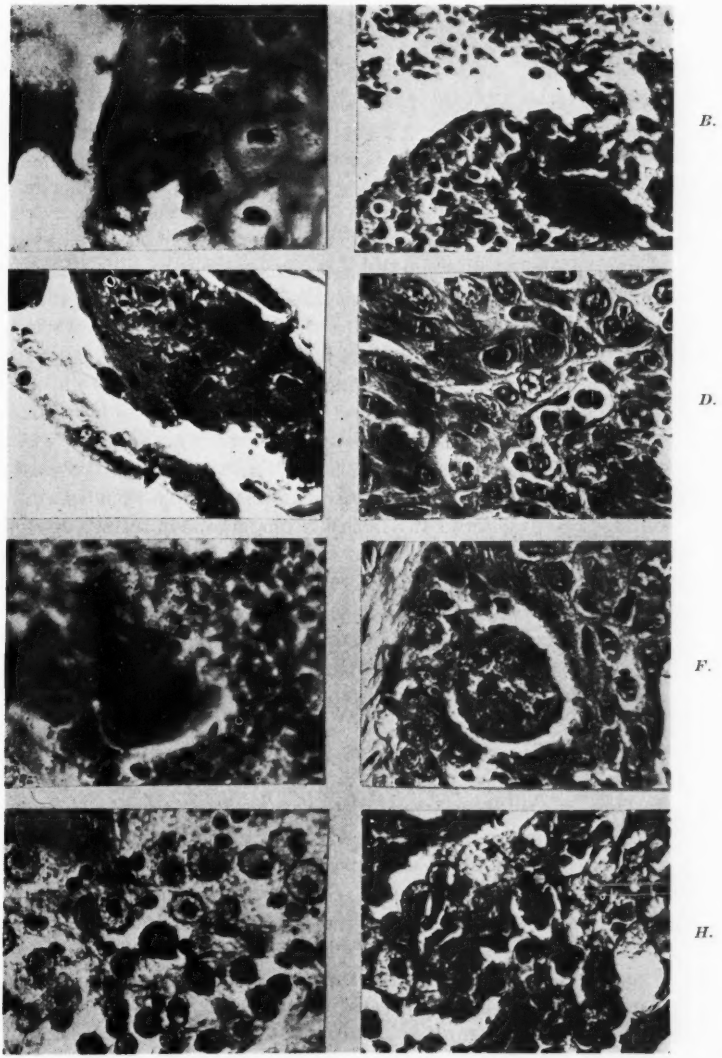

Fig. 2.—*A*, Gelfoam sponge with hyperkeratotic epithelial cell nest from a case of lung abscess (middle lobe syndrome). *B*, Tissue section from the same case, showing bronchial metaplasia. *C*, Nest of epidermoid carcinoma cells in sponge taken from trachea at site of invasion by carcinoma of esophagus. *D*, Biopsy of esophagus from the same case. *E*, Malignant cells in sponge biopsy from patient with metastatic tumor eroding bronchus. Note large numbers of red cells surrounding tumor nest. *F*, Section from excised lung showing tumor (primary site, corpus uteri). *G*, Bronchial sponge biopsy showing varying phases of adenoma cells (compare to cells in *H*). *H*, Section from lung showing development of similar cell forms within tumor.

TABLE III. INFLAMMATORY DISEASES IN WHICH SPONGE BIOPSY WAS NEGATIVE (25 CASES)

Bronchiectasis	7
Bronchitis	4
Middle lobe syndrome	3
Infarct	1
Pneumonia	4
Lung abscess	3
Tuberculosis	3

done on these sections did not reveal tubercle bacilli even though the sputum was heavily positive in every case. The remaining 18 patients encompassed such diseases as atelectasis, emphysema, silicosis, cardiospasm, myxedema, and psychogenic disorders. In none of these was a falsely positive sponge biopsy obtained.

DISCUSSION

We have been impressed with the ease of collection, preparation, and the microscopic excellence of material prepared by the sponge method. Fig. 5 illustrates sponge biopsies compared with sections obtained either by tissue biopsy or surgical extirpation. It is apparent that the cells to be examined are confined to a limited area of the slide, and sections at multiple levels can be made to investigate suspicious areas. There is uniform depth of sections, and the difficulty of overlapping pus and blood cells is thereby minimized. The standard tissue stain with which the pathologist is familiar can be used for these sections, and the interpretation therefore requires no familiarity with special stains.

The number of tumors in this series is too small for statistical significance. We were impressed, however, with the absence of falsely positive slides as well as by the positive cytologic diagnoses in two patients with negative findings at bronchoscopy. In these two cases the secretions sopped up by the sponges were the only means of making a correct preoperative diagnosis. Earlier in the series we compared the sponge method with the Papanicalaou method in each case, but shortly abandoned the latter because superior slides were obtained by the sponge method.

A sponge biopsy is usually not necessary for the diagnosis of esophageal carcinoma, since the tumor is almost always visible and a direct biopsy may be taken. Lesions of the gastric cardia, however, often extend submucosally upward into the esophagus without presenting a mucosal tumor. In these cases the sponge passed through the strictured area may pick up tumor cells. This was accomplished in one of our cases. Of perhaps more importance is the demonstration of direct tumor invasion in the posterior membranous portion of the trachea from a primary site in the esophagus. In two of our patients in whom this was suspected, no endotracheal tumor was visible but the sponges taken from the trachea contained tumor cells. Inoperability was therefore established without recourse to thoracotomy.

The differentiation between pulmonary suppurative disease alone and such inflammatory disease secondary to the growth of tumors is of vital importance. We were pleased that in our twenty-two patients with inflammatory diseases of the lungs there were no falsely positive sponge biopsies. Accurate diagnosis in this type of patient is difficult either by sputum or endoscopic Papanicalaou

examination because of the large numbers of inflammatory cells, and frequently red cells as well. The paraffin block method of preparation allows one to discriminate more carefully between inflammatory cells and those cells desquamated from tumors.

We have learned several precautions which must be observed in order to obtain satisfactory sponge biopsies. First, the sponge must remain in contact with the secretions for a sufficiently long time to allow absorption of a large number of cells. The minimum time appears to be approximately one minute. Second, when the nurse is sectioning the sponge and placing it on the sponge carrier, great care must be used not to compress the sponge with the fingers and therefore to destroy its absorptive qualities. Finally, of course, the sponge should be placed immediately in fixing solution so that there will be no distortion of the cells by drying. Greatest diagnostic accuracy may be expected when the sponge is rubbed directly on the tumor. This is not often possible endoscopically. When it is, one should also be able to obtain a direct biopsy.

We feel that the comment of Ulfelder applies to this method as well as to that of Papanicalaou, "The results are most accurate when slides are prepared by a person interested in the procedure and willing to give time and attention to details that may facilitate interpretation, and when the slides are examined by someone thoroughly familiar with the cellular pattern of that particular fluid, prepared in that particular way."[4] Other cytologic methods may be most satisfactory when handled by other people, but in our hands, sponge biopsy has proved of greatest aid.

SUMMARY

The sponge biopsy technique has been applied in a series of eighty consecutive patients subjected to diagnostic bronchoscopy or esophagoscopy. It was found useful particularly for the identification of pulmonary tumors, the distinction between inflammatory disease and tumor, the delineation of esophageal cancer which had extended into the trachea, and on one occasion for the identification of tumor cells from a gastric cancer with submucosal esophageal extension. In our experience, the technique is simple and produces microscopically more readable preparations than other currently used endoscopic cytologic methods of diagnosis. The technique of sponge biopsy is described and illustrative photomicrographs are presented.

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THE PATHOGENESIS OF BRONCHOPLEURAL FISTULAS FOLLOWING EXCISIONAL THERAPY FOR PULMONARY TUBERCULOSIS

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BRONCHIAL stump fistula accompanied by empyema is one of the most common serious complications of excisional therapy for tuberculosis. The infection often resembles the mixed infection tuberculous empyema which follows the formation of pulmonary bronchopleural fistulas. Such a fistula is a serious threat to the life of the patient, since aspirated material from the infected chest space may be the source of an overwhelming spread of the disease to the remaining lung parenchyma. It is the purpose of this paper to describe the mechanisms by which this condition may develop.

MATERIAL

We have encountered nine bronchopleural fistulas in 84 (10.7 per cent) postoperative tuberculous patients who had been treated by excisional therapy. The clinical and pathologic findings in five of these cases are described in detail, since we believe that their fistulas arose in a manner which has been subject to some controversy. Four of these five cases were studied at necropsy and one is alive and well; three of the patients had pneumonectomy, one had lobectomy, and one had a segmental resection. Since the cause of the fistulas in two cases is not subject to question, they are included in the body of the discussion which follows the case reports. Both patients had segmental resections and are still alive. The other two patients died, but are not included since they were not studied at necropsy.

CASE REPORTS

CASE 1.—This 20-year-old Negro man was discovered to have pulmonary tuberculosis in 1947. He had been well until June, 1947, when he developed malaise, fatigue, weight loss, and cough. Roentgenogram on June 26, 1947, revealed a mottled area involving the entire left upper lung field. All sputa were positive for acid-fast bacilli. Streptomycin was begun on Aug. 5, 1947, at a dosage of 0.4 Gm. every three hours. This was changed to 0.5 Gm. four times a day on Aug. 5, 1947, and continued until Nov. 5, 1947, at which time he had received a total of 200 Gm. He became afebrile and began to gain weight. A left phrenic crush was performed on Aug. 1, 1947. On Aug. 13, 1947, a left pneumothorax was induced but was ineffective because of pleural adhesions. On Jan. 28, 1948, he developed scrotal pain. This was accompanied by swelling of the left epididymis. A diagnosis of tuberculous epididymitis was made and the patient was given 38 Gm. of streptomycin in

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thirty-eight days. His symptoms subsided and the swelling abated. He was admitted to the Halloran VA Hospital on April 20, 1948, at which time his sputum was Gaffky V. The organisms were sensitive to 1 μg of streptomycin. Roentgenograms revealed an area of rarefaction above the left second anterior rib.

In June, 1948, he again became febrile, and roentgenogram revealed a spread to the left lower lobe. In view of failure of previous collapse therapy and the ineffective cough due to a permanent left phrenic crush, it was felt that resection was the treatment of choice. The right lung appeared stable. He was started on a third course of streptomycin on July 23, 1948, at a dose of 0.5 Gm. twice a day.

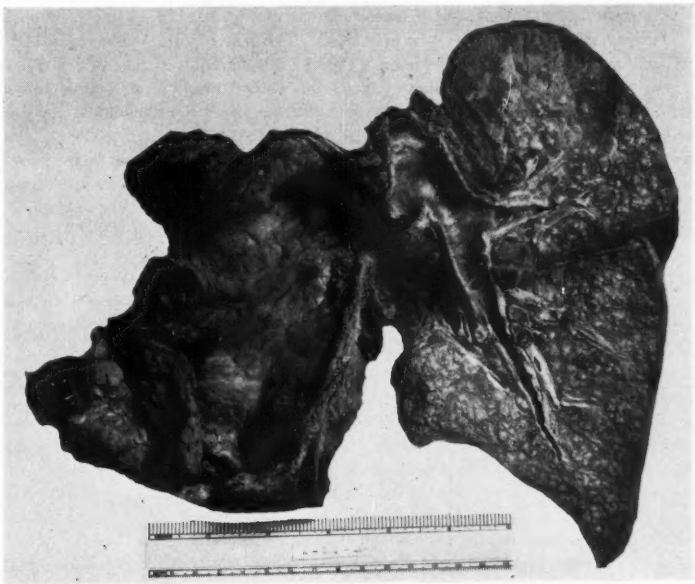

Fig. 1.—(Case 1) Tuberculous empyema with stump fistula. Note the 1 cm. segment of bronchial stump, the opening at the distal end of the stump and the large numbers of fresh tuberculous lesions in the intact lung.

A left pneumonectomy was performed on Aug. 24, 1948. It was performed with moderate difficulty and early control of the bronchus. The pleural space was obliterated by dense adhesions. The lung was contracted and fibrotic. After removal of the lung, traction sutures were placed proximal to the clamped stump which was then reamputated with interrupted sutures of 000 silk. The stump was buried with a pleural flap. The wound was irrigated with saline and the chest was closed without drainage after the instillation of 200,000 units of penicillin and 1 Gm. of streptomycin.

The patient appeared to be doing well for the first two postoperative days. On the third day he spiked a fever of 102° F. This fever continued until the twenty-first postoperative day. During this period it was necessary to aspirate an unusual amount of fluid from the left chest (3090 c.c. of serosanguineous fluid from Aug. 28, 1948, to Sept. 16, 1948, and 755 c.c. from Sept. 17, 1948, to Oct. 5, 1948). Culture of this fluid on Sept. 30, 1948, was positive for *M. tuberculosis*. On Oct. 4, 1948, *Staph. aureus hemolyticus* was also cultured from the fluid. Streptomycin and penicillin were instilled into the pleural space every other day, and subcutaneous injections of streptomycin were also continued. On the forty-first postoperative day the patient spiked a fever of 103° F., and coughed up reddish-brown material, establishing a diagnosis of bronchopleural fistula. Attempts to control the fistula

with intercostal underwater drainage were unsuccessful. The patient now developed a massive spread to the right upper lobe. The chest was reopened, and a 4 mm. stump fistula was found. This was closed with a pectoralis major muscle flap. The fistula remained closed for only three days. Respiratory insufficiency developed, and the patient died on Oct. 30, 1948 (sixty-seventh postoperative day).

Anatomic Findings.—

A. *Surgical Specimens:* Left Lung: Tuberculous cavities were present in both lobes of the left lung. Encapsulated caseous foci, which were softened centrally, were present in the lower lobe. Partially healed acinous nodose foci were present in both lobes. Although the pleura overlying the lung was thickened, there was no evidence of pleural tuberculosis. The left main stem bronchus was free of disease at its cut edge.

B. *Necropsy Findings:* Gross Examination: The left pleural space contained 200 c.c. of creamy yellow pus. The parietal pleura (Fig. 1) varied from 2 mm. to 1.5 cm. in thickness. It was lined by a layer of shaggy material which varied from yellow to red-brown in color. A 3.5 cm. sinus tract led from the pleural space to a bronchial stump measuring 1 cm. in length. The lining of this tract was similar to that which lined the pleura. The muscle flap hung free within the pleural space. The mucosa of the lower trachea and both main bronchi had a red granular appearance and contained many depressions from 1 to 4 mm. in diameter. These were most numerous in the stump of the left main bronchus.

The tracheobronchial lymph nodes adjacent to the stump were mottled gray-white and slate gray-black in color. They contained no caseous foci.

Scattered throughout the right lung were many acinous nodose foci, and areas of caseous lobular pneumonia which varied from 5 mm. to 3 cm. in diameter. These areas were most numerous in the medial and basal aspects of the lung. There were no cavities or encapsulated foci in any of the lobes of the right lung.

The mucosa of the larynx, and of the small intestine and of the colon, was intact on gross examination. The left testis was occupied by dense gray tissue.

Histologic Examination: The left pleural space was lined by a pyogenic membrane. Beyond this was a wide granulation tissue containing epithelioid cells and Langhans giant cells. Deep to this was dense collagenous connective tissue. Contained within the granulation tissue and the connective tissue in deeper portions of the pleura were large and small tuberculous foci. The former had caseous centers. Deep tuberculous ulcers were present at the carina of the trachea and within the left main bronchus. The adventitial aspects of these structures were markedly thickened, and contained many round foci. The largest of these had a central zone of caseation. Similar foci were also present in the adventitial aspects of the adjacent esophagus.

There were few healing changes about the acinous nodose foci and areas of caseous lobular pneumonia. Both types of foci were composed for the most part of caseous material containing many nuclear fragments. They were surrounded by a wide perifocal reaction.

Summary.—This 20-year-old Negro man developed a tuberculous empyema after a left pneumonectomy. On the forty-first postoperative day he developed a bronchopleural fistula. This was followed by rapid spread to the contralateral lung. At necropsy the oldest tuberculous lesion was present in the left pleural space. The right lung was free of all but recent lesions derived by bronchogenic spread from the left pleural space. As in subsequent cases the age of the lesions was estimated on the basis of the amount of healing change in the adjacent tissue.

CASE 2.—This 26-year-old white man was found to have tuberculosis in August, 1946, when it was noted that he had a cavity in the right upper lobe. He was treated at another hospital by an eight-rib thoracoplasty. This was accompanied by a ninety-eight day course of streptomycin at a dosage of 0.3 Gm. twice a day for a total dose of 58.8 Gm. The collapse obtained by thoracoplasty was poor. The regenerating ribs assumed a convex outline, and marked scoliosis developed. The cavity remained open and the sputum remained positive. The patient left the hospital against medical advice. Sputa examinations

done while the patient was at home were said to be negative. He entered Halloran VA Hospital in October, 1949, after sputum examination revealed the presence of acid-fast bacilli. Roentgenograms revealed two cavities in the right infraclavicular region associated with considerable exudative disease. The left lung appeared free of disease.

Because of the failure of collapse therapy a right pneumonectomy was performed on Jan. 13, 1950. This was done without undue difficulty. The volume of the right pleural cavity was reduced one-third by the previous thoracoplasty. There was pleural symphysis at the apex and at the superior segment of the lower lobe. There was a prolonged extrapleural dissection prior to securing the bronchus. It was not felt that considerable spill occurred when the bronchus was divided. The vessels were then isolated, ligated, and divided. The lung was then removed. The bronchus was freed of the peribronchial tissue. Traction sutures of 00 were placed posterolaterally and posteromedially. The stump was amputated at a higher level and closed with interrupted 000 cotton sutures.

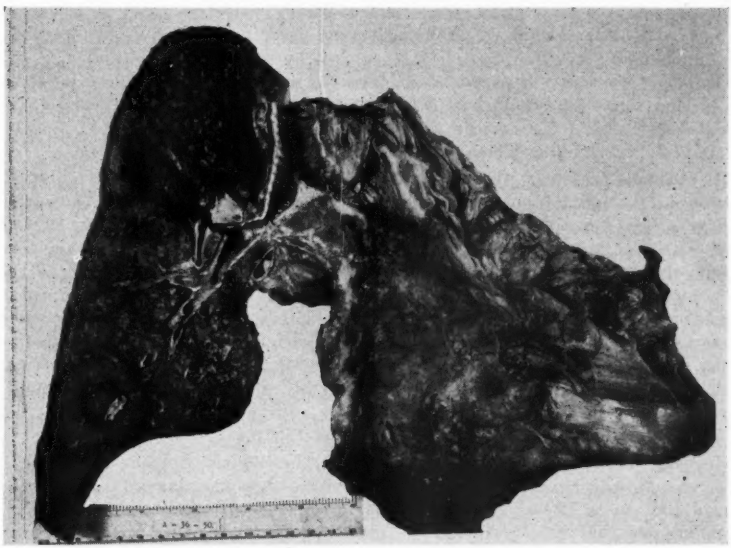

Fig. 2.—(Case 2) Tuberculous empyema with stump fistula. Note the 1 cm. segment of bronchial stump, the opening at the distal end of the stump and the large numbers of fresh tuberculous lesions in the intact lung.

Gelfoam was placed in apposition to the stump which was then buried by apposition of the mediastinal pleura to the periesophageal tissue. The pleural cavity was washed with 2,000 c.c. of saline and 30 c.c. of saline containing 1 Gm. of streptomycin and 200,000 units of penicillin. A clamped intercostal catheter was left in place inferiorly and posterolaterally. It was felt that he stood the operation well. Postoperatively he ran a fever which varied from 100° F. to 102° F. for two weeks. Culture of chest fluid at this time failed to grow *M. tuberculosis* or pyogens. The patient remained afebrile from Jan. 28, 1950, to Feb. 5, 1950 (twenty-third postoperative day). He then began to run an evening fever which rose to 100.4° F. A bronchopleural fistula was demonstrated on the twenty-eighth postoperative day. Review of chest films up to this date revealed that the left lung remained free of disease. Streptomycin was given in a dose of 0.5 Gm. twice a day, commencing on Feb. 10, 1950. The patient was bronchoscoped on February 10, and a 4 mm. opening was observed in the bronchial stump. This was cauterized with 25 per cent silver nitrate. This was repeated on February 16 and February 23, but did not stimulate

bronchial closure. On February 23 the tenth rib was excised and the pleural space was packed with gauze soaked in streptomycin and penicillin. Roentgenogram at this time revealed massive spread to the left lung. He went into respiratory failure and succumbed on Mar. 11, 1950 (fifty-seventh postoperative day).

Anatomic Findings.—

A. *Resected Right Lung:* Gross Examination: Two slitlike cavities were present in the posterolateral aspects of the upper lobe. These were lined by yellow cheesy material. Upper lobe bronchi opened widely into both cavities. The cavity wall varied from 2 to 4 mm. in thickness. The intervening parenchyma was traversed by bands of gray tissue which gave the lung in this region a solid consistency. Scattered through all lobes of the lung were many round encapsulated foci from 2 to 4 mm. in diameter. Acinous foci were present in the lower lobe. There was a pleural symphysis over the apex of the upper lobe and over the posterior, superior, and lateral aspects of the lower lobe. The combined pleurae measured 2 mm. in thickness in these regions, and were composed of dense gray tissue. The peribronchial lymph nodes varied from 5 mm. to 1.4 mm. in diameter, and on section were slate gray-black. The right main bronchus showed no evidence of gross pathologic change.

Histologic Changes: there was no microscopic evidence of tuberculosis in either the pleura or the right main bronchus. One small tuberculous focus was found in a peribronchial lymph node. The cavities were lined by a wide zone of caseation. Small round foci were present within the submucosa of the bronchi draining these cavities.

B. *Necropsy Findings:* Gross Examination: The right chest cavity was lined in part by friable yellow material and in part by a red granular tissue (Fig. 2). The cavity wall was composed of firm tissue which measured from 2 to 5 mm. in thickness. This tissue blended with the muscles of the chest wall, with the diaphragm, and with the tissue of the mediastinum. There were many small round yellow foci within the mediastinal soft tissue adjacent to the pleura. A 1.1 cm. segment of right stem bronchus remained intact. A 5 mm. opening at its distal end communicated with the pleural space. The mucosa of both stem bronchi had a granular appearance. Scattered throughout both lobes of the left lung, but most numerous in the lower and medial aspects, were many acinous nodose foci. These measured from 1 to 7 mm. in diameter. The tracheobronchial lymph nodes varied from 5 mm. to 4 cm. in diameter, and on section were slate gray-black. Numerous small round foci surrounded the right inferior tracheobronchial lymph node.

Histologic Appearance: the pleural space was lined by a pyogenic membrane. Deep to this was an edematous vascular granulation tissue containing epithelioid cells and Langhans giant cells. Beyond this was a dense collagenous connective tissue. Numerous small round foci were present in the granulation tissue and within the dense connective tissue. The epithelium of the bronchial stump was flattened where it joined the pleural space. Many small foci were present deep within the bronchial wall at this point. Collections of caseous material were present in the lumina of the bronchioles of the left lung. The walls of some of these bronchioles and portions of the adjacent lung also were caseous. These small focal areas were surrounded by a scanty vascular granulation tissue composed of epithelioid cells, Langhans giant cells, fibroblasts, polymorphonuclears and collagen fibers. Occasional small round submucosal tuberculous foci were present in the left main-stem bronchus and within the tracheobronchial lymph nodes. The latter had many fibroblasts and collagen fibers in them.

Summary.—This 26-year-old patient developed a bronchopleural fistula twenty-eight days after a right pneumonectomy. This was preceded by a febrile period, and was followed by a sudden spread to the contralateral lung. At necropsy the oldest tuberculous disease was present in the right pleura. The only lesions in the left lung were of recent origin and were derived from the right pleural space.

CASE 3.—This 25-year-old white man became ill in October, 1944, when he developed an upper respiratory infection from which he did not completely recover. Pulmonary tuberculosis was discovered in December, 1944. Sputum was positive, and roentgenogram

revealed a right upper lobe cavity with spread to the left upper lobe. A right pneumothorax was induced in February, 1945, but abandoned following thoracoscopy in April, 1945, because of pleural symphysis. Late in April of the same year a left pleural effusion developed and a cavity became evident in the fourth left anterior interspace. The effusion cleared, leaving an obliterated costophrenic sulcus. A left pneumothorax was attempted at this time, but abandoned. A right two-stage, five-rib thoracoplasty was done in November and December, 1945. Collapse was probably adequate. Sputum remained positive. A laryngitis which had the appearance of a typical tuberculous lesion occurred in December, 1946. He was given streptomycin (1.8 Gm. per day) from Dec. 9, 1946, to April 9, 1947 (217.8 Gm.). During this period he gained 10 pounds in weight, but his sputum was still occasionally positive. He was admitted to the Halloran VA Hospital in June, 1947.

Physical examination revealed a right-sided surgical collapse with some scoliosis. The right lung was clear to percussion and auscultation. There were some post-tussic inspiratory râles on the left side in the apex and posteriorly just medial to the scapula. Blood count, sedimentation rate, and urine examinations were all within normal limits. Sputum was Gaffky IX. Roentgenogram revealed a five-rib thoracoplasty with an open cavity under the major collapse. A 2 cm. cavity was present at the level of the left second rib anteriorly. There were scattered fibrotic and fibrocalcific nodules in the third left interspace.

A left phrenic crush was done in September, 1947. The left cavity enlarged during the next two months. The patient became febrile in January, 1948, and roentgenogram revealed a spread to the left mid-lung field. Further spread to the left lower lobe occurred in May, 1948. This did not clear with bed rest, and the patient again was placed on streptomycin (1 Gm. per day for forty days). A left extrapleural pneumothorax was done on Oct. 22, 1948. The cavity remained open. A small thoracoplasty (all of the second rib and diminishing segments of the third and fourth ribs) was done on Dec. 2, 1948. This in turn was followed by a segmental resection of the apical and posterior and anterior segments of the left upper lobe. The latter procedure was performed without incident.

Surgical Specimen.—Gross Examination: The specimen measured 11 cm. apicobasally, 8 cm. mediolaterally and 4 cm. anteroposteriorly. The covering visceral and parietal pleurae were fused, measuring from 3 to 5 mm. in thickness. The bronchi, including the proximal cut ends, appeared normal. A 4 cm. by 3 cm. by 1.5 cm. cavity was present in the basal aspects of the specimen. Its wall measured from 1 to 2 mm. in thickness. Occasional small encapsulated caseous and acinous nodose foci were present in the remaining portions of the lung parenchyma.

Microscopic Examination: Both acinous nodose foci and encapsulated foci were found to be in a stage of healing. The latter contained calcium deposits in the form of Liesegang rings. Many of the former consisted almost entirely of fibroblasts, collagen fibers, epithelioid cells, and lymphocytes, although some of the larger foci had small caseous centers. The thickened pleura consisted of dense collagenous connective tissue and contained large numbers of lymphocytes, plasma cells, and histiocytes. The segmental bronchus was free of foci, but contained a few lymphocytes, plasma cells, and histiocytes.

Postoperative Course: Streptomycin was given for forty-seven days (1 Gm. each day). It was necessary to leave a catheter in place for seven days. His temperature rose to 102° F. daily during the first eight days. He then ran a low-grade fever, his temperature reaching 100° F. On the twenty-third postoperative day he again began to spike a temperature which varied from 101° to 102° F. One month postoperatively his sputum increased in amount, and it became evident that a bronchopleural fistula was present. Closed catheter drainage was begun on Feb. 18, 1949. This did not control the situation, since spread of the disease to the left lower lobe was now noted. An anterior thoracoplasty was performed in April, 1949, and this area was packed three times weekly. His sputum was positive during this period of the postoperative course. The infecting

organisms were sensitive to 2.5 μg of streptomycin prior to resection. The patient's condition was quite poor, so that fistula closure could not be attempted. On Aug. 6, 1949, he developed an upper respiratory infection which was followed by a severe tracheobronchitis. His pulse rate climbed to 140 to 200 per minute, and he developed evident pulmonary edema. He expired on Aug. 12, 1949, from pulmonary insufficiency.

Postmortem Examination: The left pleural space was obliterated in the lower two-thirds by loose adhesion bands (Fig. 3). In the upper third the visceral and parietal pleura were fused by dense gray-white tissue over all but the superior aspect of the lung. The superior surface of the upper lobe formed the base of a cavity which communicated, via a sinus tract, with the chest wall at the left anterior axillary line. Yellow pus filled this cavity. A small bronchus opened into the pleural cavity. Due to distortion of the pulmonary architecture, it could not be established which segment it originally served.

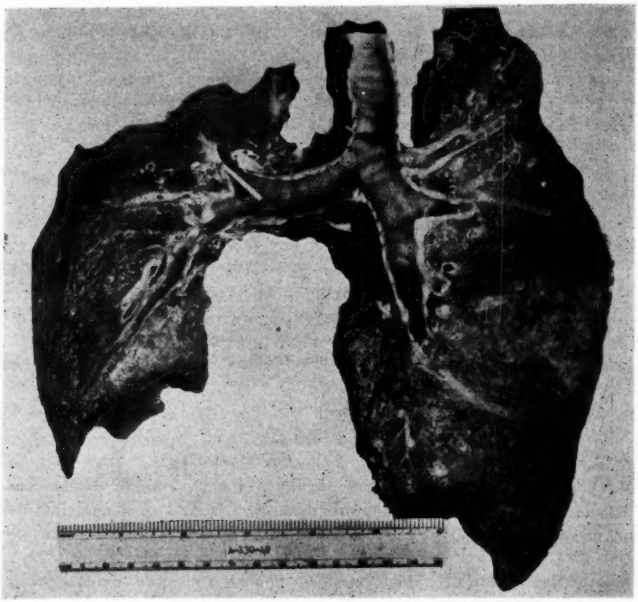

Fig. 3.—(Case 3) Tuberculous empyema following segmental resection. Probe is introduced into bronchus communicating with the pleural space. Note the large numbers of small foci of recent origin throughout the intact lung.

Scattered throughout the left upper lobe and throughout both lower lobes were numerous acinous foci which varied from 3 to 5 mm. in diameter. These were more numerous and larger than in the resected specimen. No cavities were noted in any of the remaining lung parenchyma, although a dense radial scar in the upper lobe of the right lung probably represented a healed excavation.

Microscopic Examination: Plugs of caseous material were found to fill the lumina of many bronchioles and were continuous with the central zone of caseation of adjacent acinous foci. The latter were surrounded by epithelioid cells, fibroblasts, and rare Langhans giant cells. The bulk of these foci were of far more recent duration than those observed within the resected specimen. The empyema space was lined by a wide zone of caseation. The underlying granulation tissue contained many epithelioid cells, Langhans giant cells, fibroblasts, and collagen fibers. Dense collagenous connective tissue formed the outer wall of the space. At the bronchocavitary junction the bronchial wall blended

imperceptibly with that of the empyema space. A small segment of the latter was lined by stratified squamous epithelium which underwent transition to pseudo-stratified ciliated columnar epithelium when the bronchial lumen was entered. The distal surface of the bronchial cartilagenous plate was partially eroded by an extension of the tuberculous granulation tissue from the empyema space. There was no other tuberculous disease within the bronchial stump.

Summary.—This 26-year-old patient succumbed eight months after a segmental resection. His death was due to extensive bronchogenic spread of his disease through a bronchopleural fistula from a tuberculous empyema which developed following the resection. Postmortem examination indicates no other source for the spread than the empyema. The presence of stratified squamous epithelium in the lining of the empyema space adjacent to the fistula indicates that the fistula had been present for some time prior to death. The fistula was clinically apparent one month after surgery. It appeared following a febrile period during which purulent material accumulated in the dead space.

CASE 4.—This 30-year-old Asiatic-Indian man was discovered to have tuberculosis and leprosy in 1945. A right pneumothorax was started in 1946, but was abandoned in August, 1947. In 1. 48 he became febrile, lost weight, and had a small hemoptysis. His daily sputum production during this period was 60 to 120 c.c., and the sputum was positive for acid-fast bacilli. He was admitted to the Halloran VA Hospital on April 8, 1949.

The admission examination revealed him to be emaciated, febrile (101° F.), and acutely ill. Examination of the chest revealed dullness over the right chest posteriorly and in the right infraclavicular region. Râles were also noted in these regions. Posttussic râles were heard in right posterosuperior chest and infraclavicular region. The small muscles of the hand were atrophied and there was a left peroneal paresis. There was an erythematous eruption over the elbows, wrists, knees, and feet.

Laboratory data: Sputum was Gaffky VII on plain smear. Roentgenogram revealed a fibrocaseous involvement of the upper portions of both lung fields with multiple translucent shadows bilaterally. The right costophrenic angle was obliterated.

The patient became afebrile after a month of bed rest. Streptomycin (1 Gm. per day) was started on April 5, 1949, and was continued for forty-two days. Biopsy during this period revealed the skin lesion to be consistent with tuberculoid leprosy. On May 26, 1949 the patient had a hemoptysis. Streptomycin (1 Gm. every three days) with PAS (12 Gm. per day) was again started on July 15, 1949. The PAS was discontinued after five days because of nausea, but the streptomycin was continued until Oct. 16, 1949. The roentgenographic appearance of the lungs improved, with signs of cavitation disappearing on the left side. Hemoptysis assumed alarming proportions in September, however, and it was considered necessary to perform a right extrapleural pneumothorax on Sept. 30, 1949. This procedure stopped the hemorrhage, but the sputum remained positive. In December, 1949, hemoptysis recurred and it was necessary to give refills to maintain a highly positive extrapleural pressure. Since the patient had six months of stability on the left side, it was decided to perform a right pleuro-pneumonectomy. This was done on April 11, 1950. At operation the pleural space was obliterated and was not entered. There was extensive thickening posteriorly. The extrapleural space was clear. The bronchus was closed with end-on sutures, and the stump was covered with a pleural graft.

Pathologic Examination: A. Gross Appearance: The lung measured 21 cm. apicobasally, 6 cm. mediolaterally, and 12 cm. anteroposteriorly. Anteriorly the pleura was gray-white in color and measured less than 1 mm. in thickness. Posteriorly the fused pleurae measured from 3 to 8 mm. in thickness. A film of orange material could be peeled from the outer surface of the pleurae in this region. The lung cut with increased resistance in the apico-posterior aspects. The upper lobe was shrunken. Within the posterior aspects of the upper lobe was an irregular cavity measuring 2 by 2 by 1 cm. It was lined by a friable cheesy material. Its wall measured from 1 to 3 mm. in thickness and blended in one region with the adjacent pleura. A widely patent bronchus opened into this cavity. The remainder of the upper lobe parenchyma was firm, gray-white in

color, and contained numerous encapsulated caseous foci measuring from 1 to 2 mm. in diameter. The middle lobe was resilient and well aerated. The lower lobe contained a few encapsulated caseous foci measuring 1 to 2 mm. in diameter. The intervening parenchyma was well aerated, and contained prominent alveolar sacs.

B. Histologic appearance: Neither the stem bronchus nor the peribronchial lymph nodes contained tuberculous lesions. The fused visceral and parietal pleurae were composed of dense connective tissue containing occasional lymphocytes and histiocytes laden with golden brown pigment. The surface lining the extrapleural space was covered by a thin layer of fibrin containing histiocytes laden with brown pigment and collagen fibers. There was no tuberculous involvement of any portion of the pleura. Advanced healing changes were noted about the upper lobe cavity and about the small encapsulated caseous foci in the upper and lower lobes of the lung.

Postoperative course: On May 8, 1950, a seven-rib thoracoplasty was performed. When the pleura was opened there was a small amount of fibrinous exudate on its surface. The pleural space contained thin fluid which was Gaffky I on smear and which was culture positive for tubercle bacilli. Culture for pyogens was negative. There were several 1 to 2 mm. raised yellow lesions over the lower mediastinal surface. No stump fistula was noted by the operator. A second stage was performed on May 18, 1950, removing segments of ribs eight and nine. Fluid removed at this procedure was negative. The pleural space was tapped on June 8, 1950, and a cloudy fluid was removed. This was also negative for acid-fast bacilli. Methylene blue was injected at this time, but was not expectorated. The patient ran a low-grade fever, but chest roentgenograms showed no further changes. On June 16, 1950, the right chest was again tapped and was positive for acid-fast bacilli. Methylene blue injected at this time was expectorated, confirming the presence of a bronchopleural fistula. All efforts to close the fistula were fruitless, and the patient died from an overwhelming spread to the intact lung in November, 1950.

At necropsy the intact lung was found to contain large numbers of caseous lobular pneumonic areas and acinous nodose foci (Fig. 4). Lack of healing changes in and about these foci indicated that they were of recent origin. In addition there were numerous smooth-lined, thin-walled sacs within the upper lobe. These had a ramifying structure and were lined in part by a thin layer of yellow cheesy material. These were interpreted as recent tuberculous ulcers in ectatic bronchi, since the smooth lined portions of these structures were lined by tall pseudo-stratified ciliated columnar epithelium. There were no thick-walled cavities or other evidence of old excavations which might have served as a source of infection of the pleural space.

The right pleural space was filled with thick yellow pus which was culture positive for *M. tuberculosis*. The residual space measured 17 cm. vertically and 5 cm. mediolaterally. It was lined by thick yellow material. Deep to this was a thick layer of dense gray tissue. A 1 cm. segment of the right main bronchus remained in situ. Its mucosa was red granular in appearance. A 4 cm. opening at the distal end of the stump communicated with the dead space.

In summary this 30-year-old patient developed a bronchopleural fistula sixty-six days following right pleuro-pneumonectomy. The residual chest space was culture positive for tubercle bacilli, and yellow foci were noted on the pleural surface one month after the resection. No stump fistula was seen at this time. All of the lesions in the intact lung were of recent origin, and no older lesions were noted which could have infected the pleural space.

CASE 5.—This 23-year-old Negro was found to have tuberculosis in March, 1946. Roentgenogram revealed bilateral upper lobe cavities with an extensive exudative component in the left upper lobe. Sputum was positive for acid-fast bacilli. He was put on bed rest. After one year he became febrile and began to lose weight. In May, 1947, streptomycin (1 Gm. each day) was started and continued for one hundred twenty days. He was transferred to Halloran Veterans Administration Hospital on June 23, 1947.

Examination revealed him to be moderately emaciated. Chest examination revealed a lag on the left. There was increased tactile fremitus over the left upper lobe. Broncho-

vesicular breath sounds and a few moist râles were present in the same area. The right side was clear. Sputum was positive for acid-fast bacilli on direct smear. Roentgenogram revealed that the upper two-thirds of both lung fields were involved by a fibrocaseous infiltrate with numerous areas of radiolucency. The trachea was shifted to the left.

The patient was continued on streptomycin. The right side cleared well, but he was left with a fibrocaseous disease largely replacing the left upper lobe. Sputum remained positive (Gaffky VII). A six-rib two-stage left thoracoplasty was performed in December, 1947, and January, 1948. Apicolysis was performed at the same time. Although it was a technically good thoracoplasty, the sputum remained positive. Streptomycin was again given from July to September, 1948 (54 Gm.). Streptomycin sensitivity studies at this time revealed the infecting organisms to be sensitive to 2.5 μg per cubic centimeter. On April 22, 1949, a left upper lobectomy was performed. There were dense pleural adhesions between the parietal and visceral pleura over the upper lobe. A cavity in the apicoposterior segment was entered in the course of freeing the lobe under the thoracoplasty.

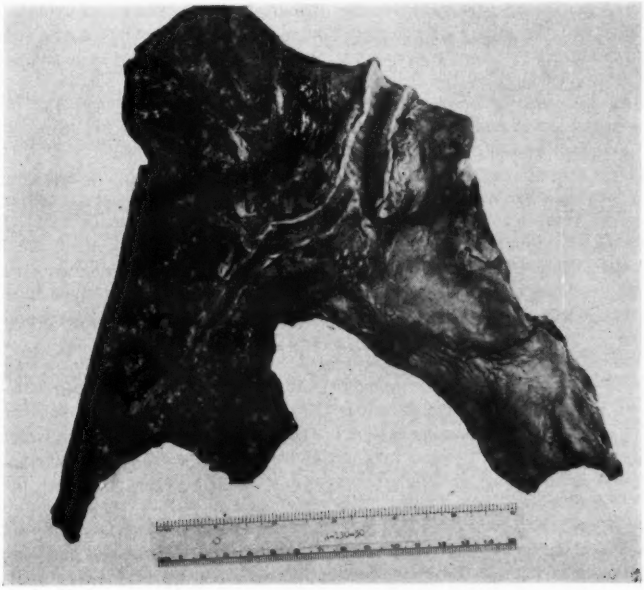

Fig. 4.—(Case 4) Tuberculous empyema, widely patent stump fistula, and many fresh lesions in intact lung parenchyma.

Pathologic Examination of the Resected Specimen: Gross: The compressed upper lobe of the left lung measured 13 cm. apico-basally, 6 cm. mediolaterally, and 2.5 cm. anteroposteriorly. The lobe cut with increased resistance. A cavity measuring 3 by 2.5 by 2 cm. was present in the lateral, apical, and posterior aspects. This was lined by a gray-yellow cheesy material. Its wall measured from 1 to 4 mm. in thickness. The lumen of this cavity communicated with the pleural surface by way of an irregular opening (surgical artefact already described). The remainder of the lobe contained several encapsulated caseous foci which measured from 1 to 2 mm. in diameter. The walls of the upper lobe bronchi had a granular appearance, but no gross ulcerations were noted. The pleura was smooth and shiny in all but the apico-posterior aspects where this segment of the lobe was dissected free from the chest wall.

Microscopic Examination: The only tuberculous involvement of the upper lobe bronchi noted was an ulcer at the bronchocavitary junction. Advanced healing changes were noted in the wall of the cavity and about the smaller foci within the lung. The pleura was without evidence of tuberculous involvement.

The patient's postoperative course was stormy. He was febrile for thirty-three days and developed a pleural effusion which never completely cleared. Unfortunately this fluid was not cultured. His sputum, except for a Gaffky I, was negative until September, 1949 (approximately one hundred thirty days), when his sputum then suddenly increased in amount and became strongly positive. All roentgenographic techniques failed to implicate the left lower lobe as the source of these organisms, but in view of the stable right lung, it was felt that the left side must contain an active focus. Bronchoscopy on Dec. 6, 1949, failed to reveal definite evidence of disease, but the mucosa at the level of the superior segmental orifice was edematous and reddened. Sputum was Gaffky VI in February, 1950. Streptomycin sensitivity was less than 10 μg per cubic centimeter. Streptomycin and PAS were started on Jan. 5, 1950, and were continued for ninety days. There was an episode of streaking in late January, 1950. On February 21 a left lower lobectomy was performed with considerable difficulty. There was an empyema space overlying the lobe and the stump of the upper lobe bronchus. The latter was covered with cheesy yellow material. There was an area just above the superior segment of the lower lobe which was very close to the bronchial stump which contained semifluid purulent material. There was also a large plaque of caseating tuberculosis over the pericardium. All caseous areas were removed with the specimen. Culture of this area revealed the presence of acid-fast bacilli but no pyogens.

Pathologic examination: The lower lobe measured 9 cm. apico-basally. The lung parenchyma was resilient and well aerated. It contained a few encapsulated caseous foci which measured from 1 to 3 mm. in diameter and a few small acinous foci. There were no areas of caseous lobular pneumonia or cavities within this portion of the lung. The pleura and the adjoining pericardium were lined by a layer of nodular gray tissue which was covered in areas by a layer of cheesy yellow material. The upper lobe bronchial stump was not available for examination. The peribronchial lymph nodes were slate gray black in color.

Microscopic appearance: The encapsulated and acinous foci in the lower lobe were in an advanced state of healing. Large numbers of small foci in an advanced state of healing were present in the regional lymph nodes. The pleura and adjacent pericardium were covered by a wide layer of caseous material. Beyond this was a pyogenic membrane composed of fibrin and polys. A wide granulation tissue composed of fibroblasts, epithelioid cells, Langhans giant cells, collagen fibers and small capillaries underlay the pyogenic membrane. Small round tuberculous foci were present within this granulation tissue. The pleura beyond this was greatly thickened by dense collagenous connective tissue.

In summary, it is felt that this patient developed a tuberculous empyema followed by a bronchopleural fistula, the latter having been the source of the acid-fast organisms which appeared in the sputum approximately one hundred thirty days after the left upper lobectomy. This assumption is supported by the fact that no source of these organisms could be demonstrated in the lower lobe, and since no organisms have been found in the patient's sputum or gastric contents since the second operation (eight months). Treatment has been effectual in clearing the pleural disease and closing the dead space. The patient has been discharged from this hospital.

DISCUSSION

For purposes of discussion we may divide the possible causes of postoperative fistula formation in tuberculous patients into several categories. We believe that it is possible that, in the future, instances of any one of them may be observed, although it seems improbable that some of these mechanisms have a great importance in this regard.

A. Erosion by an Extrinsic Lesion.—

1. *Tuberculous empyema:* Erosion of a bronchial stump by tuberculous empyema would enable the escape of infected material from the empyema space into the tracheobronchial tree, with subsequent spread of the disease to intact pulmonary tissue. This has been the commonest cause of fistula formation in our series, and we feel that it was operative in all of the cases presented. To establish this mechanism as the cause of these fistulas we must furnish evidence that the tuberculous empyema existed prior to fistula formation, and that no other tuberculous lesions existed that were capable of infecting the pleural space. These criteria are fulfilled in each of the five cases presented, although in some instances the evidence is indirect. In each of the first three autopsy cases the pleural lesion was the oldest active tuberculous lesion in the pulmonary system, and the only ulcerocavitary disease present. Such lesions as were present in the intact lung were small and were either inactive (radial scars and encapsulated caseous foci) or the result of a spread from the pleural space (recent acinous nodose foci). In the living patient (Case 5) no cavities were demonstrated in the nonexcised parenchyma prior to surgery either by standard radiographic techniques or by tomography. Such cavities as were noted in the contralateral lung (Case 4) appeared subsequent to fistula formation and represented infection of bronchiectatic sacs from the empyema space. We believe this to be true because the cavities were thin walled, followed the ramifications of the bronchi, and were not visible by roentgenogram until after the formation of the stump fistula. Bacteriologic evidence that the tuberculous empyema existed prior to fistula formation was present in Cases 1 and 4. Histologic evidence substantiated the diagnosis in Case 5. In Cases 2 and 3 a tuberculous empyema was present at necropsy, and there was no source of tuberculosis in the remaining lung parenchyma which could have infected the space after fistula formation.

It may be asked whether it is possible for a tuberculous empyema to erode a bronchus, in the face of evidence that extension into the lung parenchyma by tuberculous empyema almost never occurs.[1] It is of interest in this regard that we have seen a nonsurgical case in which the trachea was eroded by tuberculosis of the adjoining pleura. Similar erosion of the bronchial stump seems possible in the light of this observation, since the traumatized bronchial tissue would furnish less resistance to an advancing ulcerative process than would an intact trachea.

It is noteworthy that the fistulas in these cases occurred at forty-one days, twenty-eight days, thirty days, sixty-six days, and one hundred and thirty days after excisional surgery. We feel that this time lag is more consistent with the indolent course of tuberculous processes than with errors in surgical technique. Fistulas of the latter type usually appear during the first fourteen days of the postoperative period. We have found that fistula formation is often preceded by a febrile episode during which either the chest fluid or samples of the pleural tissue give evidence of tuberculous activity. We feel that any patient developing unexplained fever in the postoperative period should be studied to rule out tuberculous involvement of the pleural space. In the event

that such infection exists, every effort should be made to prevent the development of a fistula. These views parallel those stated by Kent[3] and Day and associates.[4] The former author makes the additional observation that late fistulas occur as a result of erosion by a nontuberculous empyema. We have one such case in our series of nontuberculous resections. It has been our experience, however, that there appears to be a much greater likelihood of erosion in the presence of tuberculous infection.

It remains to establish the cause of the empyema. It may be derived from contamination of the pleural space at the time of surgery. Accidentally opened pulmonary cavities or incision of frankly caseous hilar lymph nodes could serve as sources of infection. In only one of our cases (Case 5) was a cavity opened. Pus may also escape from the raw pulmonary surface by way of the alveoli and small bronchi and bronchioles. This could occur during segmental resections, or during difficult cases where the visceral pleura over the diseased lung is torn free of the pulmonary surface. One of our cases (Case 3) was a segmental resection and may perhaps have fallen into this group. Opportunity for the escape of infected secretions into the pleural space may occur when the stem bronchus is cut. Last, the empyema may represent an exacerbation or continuation of an infection existing prior to surgery. In our series, despite careful search, none of the surgical specimens showed any evidence of tuberculous involvement of the pleura. However, it is possible that small unsuspected caseous foci may have been left in situ at the time of surgery. Since pleural tuberculosis is often of hematogenous origin from an extrapulmonary source[2] it is of passing interest that two of these cases (Case 1 and 3) had genitourinary tuberculosis. It is possible that unsuspected hematogenous pleural tuberculosis existed in these cases, and that this served as a source for the subsequent empyema.

The objection might be raised that surgical contamination probably occurs more frequently than does postoperative tuberculous empyema. It is difficult to estimate the amount of contamination in any one case. Individual resistance and degree of dosage are the determining factors in any infection, and in this instance neither of these is readily measurable. Another factor which may possibly play a role in determining whether a given spill will result in a tuberculous empyema rests with the growth characteristics of the invading organism. Although the pleural dead space may furnish an ideal container for the culture of bacterial organisms, there are individual variations in the culture medium. Sensitive organisms are adversely affected in the presence of streptomycin. Hurwitz,[5] however, has shown by in vitro methods that the growth of resistant organisms is stimulated by the presence of streptomycin in a medium which varies from pH5.8 to pH6.2. This effect is most pronounced from pH6 to pH6.2. In some cases he has noted that the organisms will not grow unless streptomycin is present. It would be interesting if pH studies of pleural aspirates were combined with sensitivity studies of the infecting organisms to determine whether a similar relationship exists within the postoperative chest space.

2. *Caseous tuberculosis of the hilar lymph nodes:* Rupture of a caseous lymph node into an adjacent bronchial stump is a possible cause of fistula formation. Intact bronchi are occasionally eroded by disease extending into them from such nodes, but this is a relatively uncommon phenomenon. It does not seem likely that this might be a frequent occurrence, since it usually occurs in patients with extensive lymphohematogenous tuberculosis, and these patients are not likely to come to surgery. Usually the lymph nodes in chronic pulmonary tuberculosis are void of all but a few microscopic-sized miliary foci.

B. *Intrinsic Causes of Stump Fistula.—*

1. *Improper closure of the bronchial stump:* Technical errors must be the source of some fistulas. The frequency with which this complication is reported following excisional surgery for bronchogenic carcinoma and for other nontuberculous pulmonary lesions gives substance to this belief. It is not the purpose of this paper to catalogue all of the sources of error, but rather to assess the importance of such errors as causative factors in fistula formation. It would be surprising if errors were not committed in the treatment of tuberculosis, since the technical difficulties encountered in the surgical therapy for this condition may be equal to or greater than those attending carcinoma or bronchiectasis.

Following slough of the stump a mixed pyogenic empyema can then supervene. In the absence of a source of tuberculous infection, the empyema will remain of this type. This is an important point in distinguishing this form of fistula from one developing on the basis of an erosion by a tuberculous infection of the dead space. If, however, the pleural space has been contaminated by caseous material, or if a cavity exists in the remaining lung parenchyma which can infect the space through the fistula, it may present a clinical appearance similar to that seen following extension of a tuberculous empyema. In this case we feel that the time of onset of the fistula should be borne in mind. It is our opinion that fistulas occurring during the first two postoperative weeks should be placed in this category, since time allowances must be made for the development and progression of the tuberculous infection within the pleural space. It should also be noted that it is often difficult to give a precise date of onset in patients of this group, since the febrile episode which attends the empyema and fistula often blends with that which follows surgery. The fistulas of two patients in this series should be placed in this group. The fistulas occurred on the fifth and tenth postoperative days following segmental resection. In each case the sputum was negative for tubercle bacilli on smear and culture despite the presence of the fistulas. The fluid within the empyema space was negative for tubercle bacilli and positive for pyogens. Both of these fistulas were subsequently closed and the patients are free of active tuberculosis.

Kent[3] stated a similar concept in these words: "It is my opinion that a bronchial fistula which occurs in the first ten days after operation is a true failure of healing of the bronchial stump and that the associated empyema is of secondary origin. On the other hand, in those instances of a later leak in the bronchus, usually from three to five weeks after pneumonectomy, the cause is most commonly infection in the pleural cavity with an empyema which

escapes through the recently healed bronchus." Kent's views were derived from a study of bronchial fistulas in thirteen nontuberculous patients. Of these patients, six occurred in the first ten postoperative days, and seven were in the later group. Among seventy-eight cases of excisional therapy for nontuberculous conditions, we have encountered early fistulas in four instances. One of these four patients died on the twelfth postoperative day. The remainder followed a course similar to that observed in the two tuberculous patients already noted in this group.

There exists one technical factor which may have a bearing on the ability of bronchial tissue to resist a progressing ulcerative lesion within the pleural space. In each of the three pneumonectomies which came to necropsy, it was noted that the bronchial stump measured 1 cm. in length. It is possible that a blind sac of this size may retain sufficient infected secretions to alter local tissue resistance. It would be of interest in the future if the length of the stump were to be calculated in all cases coming to necropsy so that this factor could be evaluated.

2. *Extension of a tuberculous ulcer of the bronchus through the stump:* Tuberculous ulcers of the bronchi are, with a few exceptions, found only in the presence of cavitary disease of the lung. If a pulmonary cavity closes, or is resected, it is likely that the bronchial ulcer will heal. Therefore, it does not appear probable that such an ulcer would go on to progression after resection unless the bronchi were more severely involved than usual. If the entire thickness of the bronchial wall had undergone caseous necrosis, no technique of closure would prevent a slough with subsequent fistula formation. Bronchial disease of this degree is relatively rare, however. In any case there was no evidence that this mechanism was operative in any of the cases reported here, since histologic examination of the proximal edges of the resected bronchi did not reveal any evidence of tuberculosis. On the other hand, when tuberculous lesions are discovered in the stumps of resected lungs they are usually small submucosal foci. None of the patients in whom we have noted these foci have developed fistulas. Day and associates[4] offer additional support to this statement. They say that, in their series, cases have been noted in which adequate healing occurred when transection was carried through grossly diseased mucosa.

3. *Infection of the bronchial stump by a tuberculous cavity in the intact lung:* Too little necropsy material has accumulated to judge whether this mode of stump infection could occur. We do not believe that it was a cause of any of the cases reported herein, although we have only clinical and radiologic evidence to support this statement in the living patient (Case 5).

SUMMARY

1. Five tuberculous patients, who developed bronchopleural fistulas during the postoperative period as a result of excisional therapy, were studied with a view to establishing the pathogenesis of the fistulas.

2. Of the five patients, four died and were studied at necropsy, whereas one remains well.

3. Massive involvement of the intact lung by recent tuberculous lesions was felt to be the immediate cause of death in the fatal cases. It was felt that in each instance a tuberculous infection was derived from the infected pleural space.

4. It is felt that the principal causes of post excisional fistulas are extension of a tuberculous empyema through the bronchial stump and technical errors in stump closure. All of the tuberculous patients in whom this complication was noted fall into the first category. Comparison of this group of patients with similar patients in the nontuberculous series revealed that the fistulas occurred late in the postoperative course in the former group and tended to occur within the first fourteen postoperative days in the latter group. It is assumed that early fistulas in nontuberculous patients are due to technical errors in stump closure.

5. It is felt that the fistulas in the tuberculous patients occurred as a result of extension from a tuberculous empyema because the empyema preceded the fistula in three of the cases. In two other cases no source of pleural infection existed in the intact lung.

6. It is felt that the tuberculous empyema results from contamination of the pleural space at the time of operation, although this factor is difficult to evaluate in the individual case.

7. It is possible that an excessively long bronchial stump may harbor infected secretions which may alter the resistance of the bronchial tissue to a progressing tuberculous empyema. A greater number of autopsied cases is required to establish this as an important factor.

8. As in nontuberculous cases, early fistulas are thought to be due to failure in stump healing. If no source of acid fast bacilli exists in the intact lung to infect the pleural space, the resulting empyema is pyogenic in character. Such fistulas usually pursue a benign course. Two cases of this type were noted in this series.

9. It is felt that neither tuberculous ulcers of the bronchial stump nor hilar lymph node tuberculosis is an important source of bronchopleural fistula.

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DISCUSSION

DR. JAMES D. MURPHY, Oteen, N. C.—Having had our share of these catastrophies, sometimes I think more than our share, we have been extremely interested in the problem of bronchopleural fistula following resection for tuberculosis. Since Dr. Auerbach told us a year ago that he had evidence indicating that the cause of the fistula could usually be traced to an empyema, we have been waiting to hear the completed paper.

It is pleasing to note that his findings almost parallel our own. In a recent report we studied autopsy findings in five patients who died following a fistula. These five patients were compared to a group of twenty-two who developed postresection fistula and with our total series of resections. We found that in the five autopsied patients the bronchial stump was literally eaten away by tuberculous granulation tissue. The three groups were analyzed from every angle that we could think of. Since we could find no difference between the technical aspects of the surgery, pre- and postoperative care of the selection of cases were considered. In only one factor was there a definite trend established, and that was in the use of streptomycin. Nowadays everyone receives streptomycin long before they come to surgery. In order to obtain statistics resulting from a large series of cases, we pooled our own contribution of 186 resections with the entire series reported at the Tenth Veterans Administration Streptomycin Conference in Atlanta in January, 1951. I would like to present those results to show the deleterious effect of the previous streptomycin treatment.

(Slide.) This represents 476 resections who came to the surgeon having had previous courses of streptomycin therapy and 480 resections who had no previous streptomycin prior to their surgical prophylactic course. All of these patients were treated with streptomycin for one week before and two weeks after resection. Fistula developed in 13.2 per cent of those previously treated and only 5.3 per cent of those who had antibiotic treatment prior to the resection course.

(Slide.) Further analysis was made of those who were known to be sensitive and those who were known to be resistant at the time of resection. Fistula developed in 26.8 per cent of ninety-seven patients who were known to be resistant to streptomycin at the time of surgery. Only 10.7 per cent of the sensitive patients developed fistula. These figures were collected from a group of forty-six participating Veterans Administration study units. The surgery in these hospitals is supervised for the most part by members of this Association, so we will have to accept the fact that it was good surgery.

(Slide.) This represents our own troubles at Oteen in a group of patients in whom a resection was done for one definite indication; a residual post-thoracoplasty cavity. Thirty-nine successive patients who had no previous streptomycin treatment were resected for this indication without a fistula. In twenty-three post-thoracoplasty resections who had had one or more courses of streptomycin before coming to surgery, seven patients, or 30.4 per cent, developed a bronchopleural fistula. The relationship of previous streptomycin treatment to complications following surgery has been studied in other forms of the surgery of tuberculosis. The results following thoracoplasty and those following cavernostomy for residual cavity also indicated that previous treatment with streptomycin resulted in an increase in the number of postoperative complications.

DR. C. THOMAS READ, Phoenix, Ariz.—Recently in the literature references and articles have appeared concerning the use of streptokinase-streptodornase outside the original reporting group in New York. With the increased use of the enzymes, I would like to call attention to some of the data we accumulated and reports obtained from others regarding bronchopleural fistula. We believe bronchopleural fistula does not occur as a direct result of the use of the material, but follows more or less indirectly. At the meeting last year it was mentioned that fistulae or potential fistulae may be controlled or made dormant by the tamponade effect of fibrinous debris. Streptokinase-streptodornase are fibrinolytic and possess the unique qualities of dissolving nucleoprotein, and they therefore could remove the tampon effect mentioned. In pulmonary resection cases it is well to keep these points in mind if indications arise for the use of the enzymes.

DR. HERBERT C. MAIER, New York, N. Y.—I think a word might be said to try to clarify some of the confusion as to the incidence of bronchial fistula in relation to streptomycin therapy. It would seem that the best results in so far as avoidance of fistula is concerned occur either when excisional surgery is done with the first course of streptomycin while the bacilli are still streptomycin-sensitive, or after a very prolonged uninterrupted course of streptomycin combined with PAS. It seems to me that the highest inci-

dence of fistula occurs where an intermediate amount of streptomycin has been used in several short courses. Then one has lost some of the beneficial effect of the streptomycin and bacterial resistance may have developed, but one has not yet obtained the maximum subsidence of the tuberculous process. This is particularly important if bronchial disease was present close to the line of section of the bronchus. Therefore, if you cannot or do not consider it advisable to do the excision with the first course, it is best to wait some months for the long course of streptomycin and PAS, in order to have maximum subsidence of the tuberculous process in the bronchus and elsewhere at the time of excision.

DR. IRVING A. SAROT, New York, N. Y.—The studies of Dr. Stemmermann and his colleagues provide a valuable confirmation of the published views of Tchertkoff and Selikoff that some postpneumonectomy bronchopleural fistulae occur as a result rather than as a causative factor of postoperative empyema. It has been in an effort to reduce the incidence of such empyemas that removal of the parietal pleura has been recommended in the course of all pneumonectomies for tuberculosis, not only because bits of tuberculous plura and involved lung remaining after a difficult intrapleural dissection may be the source of the empyema, but also because the parietal pleura becomes infected easily as a result of contamination during operation.

(Slide.) Extrapleural pneumonectomy (pleuropneumonectomy) was developed to overcome the difficulties in resection occasioned by the presence of dense pleural adhesions (symphysis) or empyema. This procedure reduces the incidence of contamination of the operative field due to rupture of lung, cavity, or empyema pocket, and also removes the parietal pleura which reacts to infection so vigorously by exudation and caseation. All the parietal pleura should be removed. Total removal of the diaphragmatic pleura, while most desirable, may be difficult due to the anatomic peculiarity of the underlying connective tissues which make for more intimate attachment of the pleura in this region. When, inadvertently or unavoidably, significant portions of the costal or mediastinal pleura are not removed, the incidence of empyema will increase. Surgical exploration of a number of cases of empyema following pneumonectomies considered to have been done extrapleurally has revealed the presence of residual parietal pleura.

Study of a large series of consecutive pneumonectomies performed by the various surgeons on the staff of Dr. L. R. Davidson at Sea View Hospital revealed significant differences in the postoperative results of intra- and extrapleural pneumonectomies.

(Slide.) Of 118 consecutive pneumonectomies for tuberculosis without empyema, seventy-five were done intrapleurally and forty-three extrapleurally. Among the seventy-five intrapleural pneumonectomies, in which the parietal pleura was permitted largely to remain in situ, there were thirteen postoperative empyemas with eleven deaths. Most of these empyemas were associated with bronchopleural fistulae, and clinical evidence was clear that in many of the cases the empyema preceded the opening of the bronchial stump. In the forty-three extrapleural pneumonectomies in this series, there were no postoperative empyemas, despite obvious gross contamination from rupture of a cavity at operation in four cases.

Therefore, especially as it has no indispensable function after pneumonectomy, it seems proper to remove the parietal pleura in every pneumonectomy for tuberculosis, as the incidence of postoperative empyema and bronchopleural fistula is thereby reduced. This is not to say that pleuropneumonectomy is not occasionally followed by either a bronchopleural fistula or empyema, or both, since they do occur although much less frequently; but they manifest a less toxic course.

(Slide.) The extrapleural dissection which circumvents dense adhesions and matted hilar nodes facilitates a rapid approach to the carina and permits a high amputation of the bronchus with resultant short bronchial stump. In two cases, Dr. Stemmermann noted at autopsy bronchial stumps 1 cm. in length. Such long stumps are prevented from retracting into the mediastinum by adherent peribronchial and pleural connective tissues. They are then more liable to open primarily because of failure of surrounding tissues to cover them, or to be eroded secondarily by empyema.

DR. RICHARD H. OVERHOLT, Brookline, Mass.—Very little has been said in this discussion about the manner in which the bronchus is closed. It has a bearing on the incidence of empyema. I am sure that almost everyone here has his own pet method of effecting a satisfactory closure of the bronchus. I have personally come to the conclusion that mattress sutures should be avoided and that something should always be done to the cartilage in order to prevent tension on end sutures. A radical change in the type of bronchial closure was made two years ago and in 228 consecutive bronchial closures there has been just one fistula.

(Slide.) I would like to illustrate this simple method. Possibly some of you use it. No clamps are used on the proximal side of the bronchus. The bronchus is only partially divided at first. The attached lung and bronchus are used for traction. Two cartilages are cut at their center from within. The first suture is passed through the end of the bronchus about midway between the membranous portion and the point of fracture of the cartilage, then out and in through the membranous wall to the opposite side of the bronchus. When this suture is set, the membranous wall becomes inverted to reduce the bronchial width by half. A second suture is placed above and a third below the first. Usually three end sutures are sufficient. The use of a minimal number of sutures prevents devascularization of the stump and will do more to prevent difficulties with healing and infection of the space than any other single step.

DR. ROBERT M. JANES, Toronto, Ontario.—After hearing Dr. Overholt's discussion I felt that it was probably up to me to make what might be considered a confession, because we have always believed in the simplest possible closure of bronchial stumps and we still use a simple running suture of chromic catgut, being careful to apply it so that it does not produce tension and interfere with nutrition of the end of the stump. I think that the important factors are the same as in surgery of the bowel, surgery of the colon, the least possible trauma, and closure without tension on the tissues and without tension on the sutures.

I have been most interested in the bringing forward of these problems. It seems to suggest thought along other directions than methods of complicated closure which I am quite sure are not the answer to this problem.

DR. STEMMERMANN (closing).—I want to thank the discussors. First, with regard to streptomycin, I do think there is one interesting factor that should be emphasized. Environmental factors may affect the growth characteristics of the invading organism, streptomycin adversely affecting organisms sensitive to the drug. It is interesting, however, that Hurwitz has shown by in vitro methods that the growth of resistant organisms is stimulated by the presence of streptomycin in a culture medium which varies from pH 5.8 to 6.2, the effect being most pronounced from pH 6.0 to pH 6.2. In some cases he has actually noted that the organism will not grow unless streptomycin is present under these conditions. It would be interesting in the future if pH studies of pleural aspirates were combined with sensitivity studies to determine whether a similar relationship exists within the chest fluid. Types of technical errors were not elaborated, since we wished only to assess the importance of errors in the pathogenesis of fistulas.

BRONCHIECTASIS: A COMPARATIVE STUDY OF TUBERCULOUS AND NONTUBERCULOUS PYOGENIC SUPPURATIVE DISEASE

JOSEPH GORDON, M.D., RAY BROOK, N. Y., AND PHILIP C. PRATT, M.D. (BY INVITATION), SARANAC LAKE, N. Y.

THIS presentation of a comparison between tuberculous and nontuberculous bronchiectasis will be limited to four points. In the formal completed manuscript other data will be considered. The term bronchiectasis is an unfortunate one, since by definition it means only dilatation of the bronchial tubes, but by inference and common usage has come to mean a disease entity. Nontuberculous bronchiectasis as used in this instance is that disease entity which commonly appears in young children and continues through later years, usually associated with cough and expectoration of large amounts of purulent foul smelling and tasting sputum. This, of course, is the type of disease that is generally meant when the word bronchiectasis is used, without other qualifying terms. Tuberculous bronchiectasis commonly means an associated disease of the bronchi in a patient with pulmonary tuberculosis. Often no distinction is made as to the level of the order of the bronchial tree that may be implicated. However, this immediately becomes clear when bronchograms are done and the abnormal dilatations are noted. This, then, gives a reference point when it is used in tuberculosis as in nontuberculous bronchograms.

The points of comparison that are being here made and illustrated in the slides are as follows:

1. Segmental lobar location of tuberculosis versus nontuberculous bronchiectasis. That either of these two diseases may involve an entire lung or may be present on both sides of the chest is recognized. Tuberculosis, as is well known, is commonly located in the posterior and apical portions of the lung segments. In contrast to this, nontuberculous bronchiectasis is commonly located in the posterior and basilar portions of the lung. In addition, tuberculosis in the apical posterior portions of the upper lobe is not uncommonly associated with disease in the superior segment of the lower lobes. This has been of more recent appreciation during exploration at the time of pulmonary resection for tuberculosis. There is a similar parallelism in nontuberculous bronchiectasis in that disease located in the posterior portions of the lower lobes often has contiguous upper lobe involvement in the lingula on the left and middle lobe on the right. In addition, in recent years, a clinical syndrome has been recognized of pneumonitis with bronchiectasis involving the right middle lobe alone.

2. Bronchograms. Tuberculous and nontuberculous cases show some similarities in that dilatation of the bronchi are thereby depicted. However, by

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direct comparison, whether in the presence or absence of cavitary disease in tuberculosis, two differential points have been noted. These are that in the tuberculous case the bronchograms show evidence of dilatation interpreted as bronchiectasis, but the filling is in the medial two-thirds of the lung field and distinctly absent from the outer portion of the lung field. In nontuberculous bronchiectasis the distinguishing characteristic is that, while a smaller sized lobe than normal is seen, the dilated bronchi extend to within the visceral pleural margin of the lobe. This has not been seen in tuberculosis.

3. A further point, as recognized in the bronchogram films, is that when these films are taken in both inspiration and expiration one sees little, if any, change in caliber of the dilated bronchi in nontuberculous cases, whereas in the tuberculosis cases one notes relatively normal behavior of the bronchi, for in expiration they are seen to decrease in size.

4. A fourth point of difference observed in this study between tuberculous and nontuberculous bronchiectasis has been observed in a study of films after injections of surgical and postmortem specimens with iodized oil. The contrast medium was injected into the bronchi and pulmonary arteries. In pulmonary tuberculosis one sees, as is well known, evidence of obliterative arteritis, and this same obliterative change is seen in the bronchi as well. Again dilatation of the larger bronchi is seen with shortening, widening, and lack of arborization, in addition to the fact that the abnormal shadow is seen to stop well within the inner portions of the lung and to be absent from the outer third. This is in striking contrast to findings in nontuberculous bronchiectasis studied in the same manner. Here one sees most strikingly that the pulmonary arterial system is completely intact, that the bronchi have the same widened appearance as noted in bronchograms with irregular margins and few or no branches, and extend to within the pleural margin of the lobe. These two distinct patterns, as above described, have been repeatedly demonstrated in all cases of bronchiectasis studied thus far, and are a constant finding in tuberculosis.

When one reviews the histopathology in the two diseases, it is easy to understand how these two patterns are demonstrable in the roentgenograms of injected specimens. The commonly seen necrotic destructive lesion of tuberculosis involves all elements of the lung parenchyma, including the bronchi and pulmonary arteries, or in some areas dense scar tissue replacement is seen to efface the smaller arterial branches as well as the bronchi and bronchioles. The bronchi toward the hilum are seen to be uninvolved, as the entire structural element appears intact. There are individual exceptions which are readily recognized. One is specific tuberculous inflammation or ulceration followed by stenosis of a major bronchus, and here the picture is that of narrowing of the lumen associated with some distal dilatation, but this is not the pattern here referred to as bronchiectasis. The pattern of bronchiectasis as described in the roentgenogram, following the use of iodized oil, is the most common one and, while these bronchi are seen to go to the lobe or portion of the lung that is extensively involved, they themselves appear intact and uninvolved by the specific disease.

A study of the histopathology of bronchiectasis which has been done repeatedly, carefully, and by many members of this association is well recognized. Here one sees that the chief insult to the lung is the tubular system itself. Variable changes of mucosa, muscularis, cartilage, and elastic membrane are described, ranging from increase in amount to decrease to absence of various portions. There is only little change in the lung parenchyma beyond collapse of alveoli, and these changes are in the contiguous areas of involved bronchi. The dilated tubular structure is seen to extend to within the margin of the pleura of the lung. Despite all of these changes in the tubular system, the pulmonary arteries have a normal appearance—they are thin walled and show no reaction.

These, then, represent the points of comparison that are being made between tuberculous and nontuberculous bronchiectasis: (1) location in the lung; (2) changes during inspiration and expiration; (3) difference in extent of tubular change as seen in the bronchogram; and (4) difference between the pulmonary arterial system in the two diseases, being greatly obliterated in tuberculosis and intact in the nontuberculous disease. Recently it has been possible to find correlation of these observations made from the injected specimens when studying patients. That is, the bronchogram observations can be made from films taken when this examination is done on the living patient and, though only a very few patients have been studied, there is a suggestion that angiocardiography with visualization of the pulmonary artery the arterial system gives similar findings. In chronic pulmonary tuberculosis the angiocardiogram reveals a paucity of arterial pattern in the involved lung area. In bronchiectasis, nontuberculous, a relatively good pulmonary arterial pattern has been seen.

The question of congenital or developmental nature of nontuberculous bronchiectasis has, to the present, not been mentioned, and is included here only to suggest a means of studying this problem. In a cystic lobe which, when removed, had classical markings of being a developmental defect, the pulmonary artery was injected, and it was noted that while the arterial pattern was present it was much smaller in caliber size, there were many fewer branches, and the entire picture was in contrast to a normal lung and to a bronchiectatic lung. In another case of what appeared to be cystic disease of the lung by bronchography, often called cystic bronchiectasis, a pulmonary angiogram showed a marked decrease in pattern. These two cases suggest that there may be a possibility of distinguishing congenital or developmental defects from acquired changes by studying the pulmonary arterial system both by angiography and direct injection of the specimen. It would seem that as an economy in nature and on teleological grounds the pulmonary arterial system might not be expected to develop normally if the need for it were not at hand as in absence of or failure of development of the lung.

FUNCTION TESTS IN PULMONARY SURGERY

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GUIDED by accumulated experience, we are able to perform major pulmonary operations on a yearly increasing number of patients. These interventions more or less inevitably reduce the respiratory area of the lungs. It is very often possible to predict, without the use of complicated tests, and with a fair degree of accuracy, how much surgery may safely be contemplated. But most thoracic surgeons have certainly had the distressing experience of producing respiratory cripples from operations where the reduction of functioning lung tissue was unexpectedly excessive for the patient. On the other hand, there are patients who are at present denied the surgery from which they might derive great benefit. Could the functional prognosis in these "borderline cases" be assessed by accurate tests of respiratory and cardiac capacity, operative treatment might be successfully undertaken.

We maintain that, in order to help patients of this latter category, and to provide a more accurate basis for evaluating surgical risks, every specialized chest unit should include a well-organized laboratory for cardio-respiratory investigations. The head of the laboratory should be a "chest-minded" physiologist with his own technical staff at his disposal. Much valuable work has been done where such laboratories are already in existence, particularly at the Bellevue Hospital, New York, by Cournand and Richards and their associates.

Respiratory function is a very complicated process involving heart, lungs, blood, and tissues; tests of function fall into two principal categories: (1) those which include all the participating factors, e.g., exercise tests; (2) those in which an attempt is made to evaluate, as far as possible, the elementary functions. Exercise tests are widely used, and if satisfactory results are thereby obtained, further analysis of the elementary components may be unnecessary. But in the event of demonstrated insufficiency, i.e., if the patient is dyspneic on exertion, the elementary functions must be carefully investigated for possible causes. Dyspnea in many borderline cases does not necessarily contraindicate operation. In such patients surgery need not increase, and may even relieve dyspnea. But if, for example, pulmonary emphysema is the causative factor in respiratory insufficiency, operation is often contraindicated, or, if attempted, must be carried out with extreme caution.

FORMS OF PULMONARY INSUFFICIENCY

Dyspnea in chest patients is almost invariably of cardiac or pulmonary origin. Heart disease must, of course, be excluded by routine methods of investi-

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gation. Remaining then are the patients whose dyspnea is attributable to pulmonary anomalies.

Only ten years ago little had been done about the problem that these cases presented. During recent years, however, much new scientific research has been carried out in this field, and it is now possible to demonstrate the direct cause of dyspnea in most cases. It has been shown that most forms of pulmonary dyspnea have their origin in well-defined pathologic changes in one or more of the following physiological entities: (1) the ventilation system, including the air passages and the movements of the diaphragm and chest wall; (2) the pulmonary parenchyma, including both quantitative and qualitative changes in the respiratory membrane of the alveoli; (3) the pulmonary circulation. Consequently, the causes of pulmonary dyspnea may be grouped as follows: (1) *Ventilation insufficiency,* which may be produced by obstruction of any kind in the air passages; e.g., tuberculous strictures, tumors, enlarged bronchial glands, etc., or by impairment of costal and diaphragmatic mobility. Overlapping from this group into the next is enlargement of respiratory dead space by bronchiectasis, pulmonary emphysema, etc., which often produce severe dyspnea. (2) *Parenchymatous insufficiency,* which occurs when the size of the functioning area has been reduced: (a) quantitatively, by disease, collapse procedures, or extirpation of lung tissue; (b) qualitatively, by impaired diffusion of gases through the alveolar membrane due to toxic agents or stasis. (3) *Insufficiency of the pulmonary circulation,* which may be brought about by: (a) persistent circulation through unventilated parts of the lung, so that unoxygenated blood is mixed with arterial blood; (b) arteriovenous aneurysm, (shunt); (c) obstruction of the pulmonary artery by emboli or obliterative arteritis.

This classification is, of course, rough, and in many respects incomplete, but it is useful in practical work where it is helpful to have a working hypothesis. Naturally the categories frequently overlap, as many conditions present combined forms of insufficiency.

TESTS OF PULMONARY FUNCTION

Theoretically, pulmonary function should be investigated with exercise tests both in its entirety and with reference to its various components. In practice, however, a few procedures, which we will now discuss, and which may be carried out with the patient at rest, have proved adequate. As certain of the functions investigated, such as residual air and maximal ventilation capacity have a pronounced correlation to the degree of dyspnea, the need for exercise tests has not been greatly felt. But we feel that exercise tests are nevertheless advisable, so as to be able to form an accurate assessment of the patient's limits as regards ventilation and oxygen uptake.

RADIOLOGICAL INVESTIGATION

Fluoroscopic and radiological investigation of the costal and diaphragmatic movements is of great value. Impairment of diaphragmatic mobility by intrapleural adhesions has an especially deleterious effect on ventilatory function; it is without doubt the commonest cause of ventilation insufficiency dyspnea. A

rough estimate of ventilation capacity on either side can be made by fluoroscopic study during forced breathing. We have found that registration of the maximal diaphragmatic movements by double exposure on the same film is very useful. This can be done without any special apparatus, but we prefer to use a lead grid with vertical lead bars, each ½ cm. in breadth and ½ cm. apart (Birath and Källqvist). Exposure is made at maximal inspiration; then, with the patient's position constant, the grid is shifted ½ cm. to one side and maximal expiration is registered on the hitherto unexposed strips of film. By thus covering the already exposed film strips, actual double exposure is avoided. Registration of the diaphragmatic movements in this simple way does not restrict knowledge of the ventilation potentialities to the observer behind the fluoroscopy screen. To be complete, the film must clearly show the posterior costophrenic sulcus. Lateral double-exposure films, with the patient in slightly oblique position should, therefore, also be taken. Not only can significant pleural adhesions be estimated qualitatively in this way. Impaired diaphragmatic function in emphysema and reduced costal movements in pulmonary retraction and pleural thickening can also be assessed.

SPIROMETRIC INVESTIGATION

The *total lung volume and its subdivisions* are also estimated. We wish to stress that measurement of the vital capacity alone is inadequate and may even be misleading. In emphysema, for instance, the vital capacity is often very good despite impaired lung function. Yet many of these patients do not tolerate the usual pulmonary operations (see Fig. 1). This is easily understood when we consider that vital capacity refers only to the function of the pulmonary bellows, but gives no information about the circulation or exchange of gases in the lungs.

If the total lung volume is estimated in such a patient, it is found to be surprisingly great, but the residual capacity, i.e., the amount of air remaining in the lungs after a maximal expiratory effort, is increased. Residual capacity (or residual air), normally constitutes about 25 per cent of the total lung volume, but in emphysema it is increased to 30, 40, or even 50 per cent. The increase applies also to equilibrium capacity (functional residual air, mid-capacity), i.e., the amount of air remaining in the lungs after a *normal* expiration. This comprises about 50 per cent of the total lung volume in a healthy subject, but may be as much as 60 to 70 per cent in pulmonary emphysema (Fig. 1).

Contrary to what appears to be the general opinion, emphysema is not the only cause of disproportionate increase in these values. In serial investigations of patients with various pulmonary diseases (Birath), it was found that relative increase of residual and functional residual air was present in patients with dyspnea on slight exertion or even at rest. This dyspnea could also be caused by other ventilation-impairing conditions, e.g., bronchostenosis, bronchiectasis, indurated or infiltrated parenchyma, and extensive pleural adhesions (see Fig. 2).

Previously, Hurtado and associates had stated that the degree of respiratory insufficiency in pulmonary emphysema is directly proportional to the percentage of residual air: But this dictum seems also to be applicable to other types of pulmonary dyspnea.

It was quite evident in one of the author's investigations (Birath), that this increase in the percentage of residual air was not bound to a diminished total capacity. In patients with bilateral pneumothorax, the total capacity could be reduced considerably without any significant change in the relationships between the subdivisions of the pulmonary volumina, as long as the lungs were adequately ventilated. On the other hand, patients with pronounced ventilation distress and marked dyspneic tendencies as a result of post-pleuritic pulmonary retraction showed marked disparity in these relationships; residual air was sometimes as much as 50 per cent and functional residual air, 70 per cent.

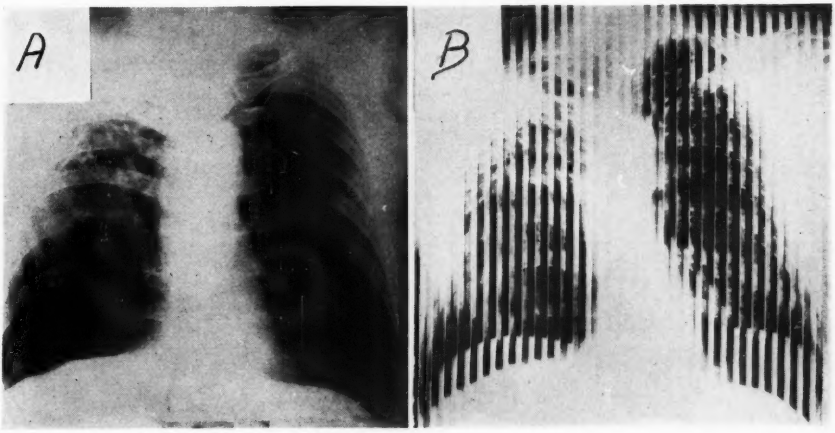

Fig. 1.—Emphysema. Unfit for operation.

A. K., a 55-year-old man. Bilateral pulmonary tuberculosis with bronchiectasis and right cavitation was diagnosed in 1949 (*A*). Double exposure on maximal inspiration and expiration shows the reduced movements and flattened contour of the diaphragm (*B*). He is dyspneic on exertion. Thoracoplasty is ruled out from a functional point of view.

SPIROMETRIC INVESTIGATION

	NORMAL VALUES (calculated)	ACTUAL VALUES
Absolute values (in liters, 37° C. saturated)		
equilibrium capacity	3.18	5.41
vital capacity	5.1	4.16
residual capacity	1.52	3.87
total capacity	6.62	8.03
Relative values (per cent of total capacity)		
equilibrium capacity	48.0	67.4
residual capacity	23.0	48.2
Maximum breathing capacity (liters per minute, 37° C. saturated)	109	31

As the fraction of special interest, residual air is fairly consistently increased in dyspnea-producing conditions, its determination gives valuable information of the functional condition of the lungs.

In our view, it is clear that indications for surgical interventions should not be bound to fixed values of the vital or total capacities. Estimation should rather be based on the percentage values of residual and functional residual air. Good vital capacity with increased residual capacity indicates inadequate rather than efficient function (see Fig. 1). Low vital capacity but normal percentage of residual air often permits pulmonary surgery (see Fig. 3).

The determination of the "*maximum breathing capacity*" according to Hermansen is also of decided value. This test demands perfect cooperation between investigator and patient, but an intelligent, willing subject can help us to obtain useful knowledge of his maximum ventilation capacity. The patient is instructed to breathe as deeply and as rapidly as possible for fifteen seconds; this is repeated at intervals until consistent values are obtained. In healthy

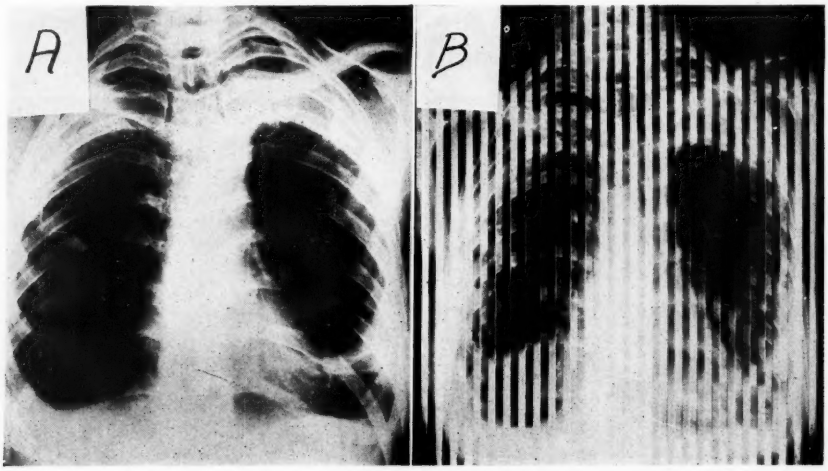

Fig. 2.—Ventilation insufficiency after bilateral pneumothorax.

S. E., a 38-year-old woman. Onset of tuberculosis (left infiltration) in 1946. Left pneumothorax was induced in July of that year. Right pneumothorax was induced in 1947 to control spread of the disease. Both pneumothoraces were discontinued in February, 1950 (*A*). Double exposure film on maximal inspiration and expiration (*B*) reveals moderate diaphragmatic insufficiency due to impairment of mobility by pleural adhesions. The patient is dyspneic on exertion.

SPIROMETRIC INVESTIGATION

	NORMAL VALUES (calculated)	ACTUAL VALUES
Absolute values (in liters, 37° C. saturated)		
equilibrium capacity	2.24	1.45
vital capacity	3.60	1.48
residual capacity	1.27	0.92
total capacity	4.87	2.40
Relative values (per cent of total capacity)		
equilibrium capacity	46.0	60.4
residual capacity	26.0	38.3
Maximum breathing capacity		
(liters per minute, 37° C. saturated)	87	41

males the range in liters per minute is 125 to 150, and in normal females 80 to 110. Cournand and Richards have found that the immediate postoperative period may be stormy, and that permanent disability in the form of dyspnea on minimal exertion or even at rest may result if the preoperative maximum breathing capacity does not exceed 30 to 40 liters per minute.

BRONCHOSPIROMETRY

The foregoing tests refer to both lungs working in unison, but often do not suffice for a thorough evaluation of pulmonary function. Let us consider a

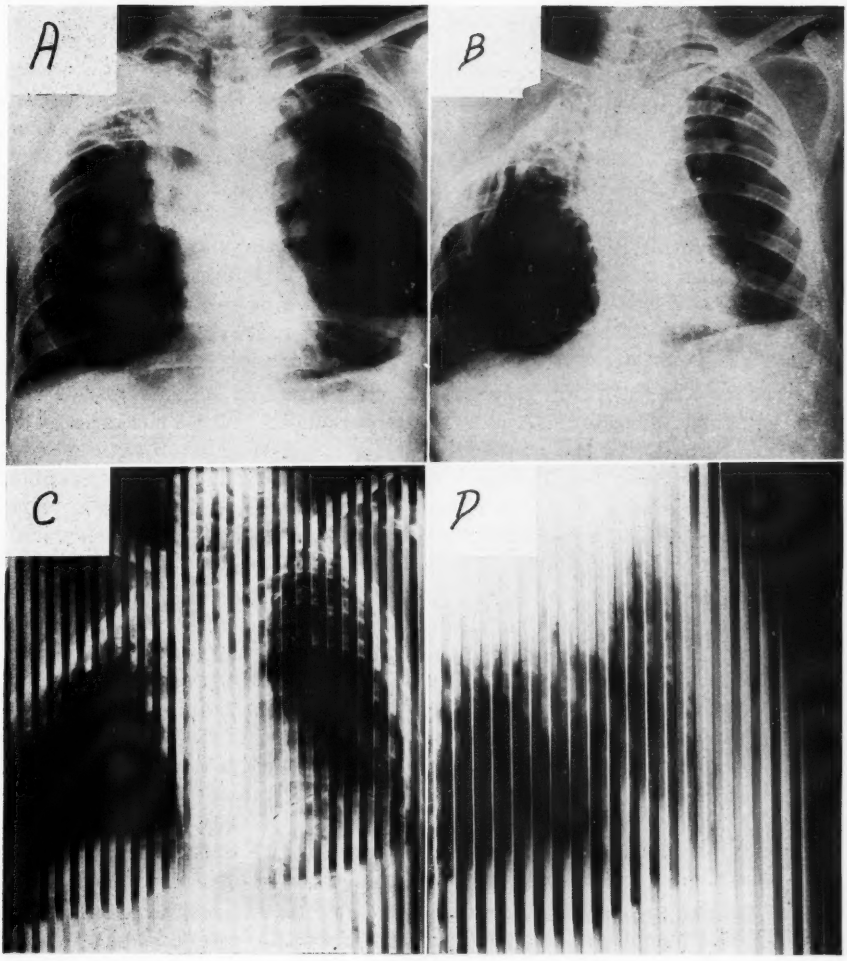

Fig. 3.—Ventilation insufficiency, fit for operation.

H. H., a 41-year-old man. Bilateral cavitary disease was discovered in 1934. Artificial pneumothorax was maintained from 1935 to 1939 on the right and from 1936 to 1942 on the left. The left pneumothorax was reestablished in 1943. Subsequently, there was bilateral impairment of diaphragmatic mobility with moderate ventilation insufficiency. The cavity in the right lung recurred and slowly increased in size. After re-expansion of the left lung and preliminary P.A.S. and streptomycin medication (*A*), two-stage thoracoplasty with extensive apicolysis was performed in August and September, 1949. Extrafascial pneumothorax was maintained in the apicolysis space for three months. The patient is now managing his iron-plating works and has no appreciable dyspnea on moderate exertion (*B*). Double exposure on maximal inspiration and expiration with grid (Birath & Källqvist) shows the movements of the diaphragm (*C, D*).

SPIROMETRIC INVESTIGATION

	NORMAL VALUES (calculated)	ACTUAL VALUES	
		BEFORE OPERATION	AFTER OPERATION
Absolute values (in liters, 37° C. saturated)			
equilibrium capacity	3.18	1.44	1.53
vital capacity	5.1	2.16	1.87
residual capacity	1.52	0.85	1.05
total capacity	6.62	3.01	2.92
Relative values (per cent of total capacity)			
equilibrium capacity	48.0	47.8	52.4
residual capacity	23.0	28.3	36.0
Maximum breathing capacity (liters per minute, 37° C. saturated)	121	44	35

patient with very limited respiratory reserves: if the pulmonary disease is unilateral, even if the lung appears to be totally destroyed by, e.g., a tuberculous process, or by neoplasmic occlusion of the main bronchus, the decision is not difficult. Total thoracoplasty or pneumonectomy will produce only temporary functional disturbance, with a subsequent return to approximately the preoperative level. But if pulmonary and/or pleural anomalies are present bilaterally, it may be impossible to decide by the above tests which lung has the better function. In such a patient, the function of each lung must be investigated separately (see Fig. 4). Should it be found that the lung requiring surgical treatment has the better function, we must act very cautiously or omit operation. But if the reverse is true, the decision is easily made, and we may proceed with confidence.

The main indication for bronchospirometry, therefore, is limitation of function by bilateral disease, most commonly tuberculosis. With some experience, it is not impossible to make a rough estimate of the function of each lung in relation to the total. Radiographs, fluoroscopic examination, double exposure in maximal inspiration and expiration give valuable help. But as even very experienced investigators may make mistakes in such patients, we are convinced that it is wiser not to evaluate roughly, but to investigate fully the pulmonary function.

We use the Björkman double spirometer, which consists of two Knipping spirometers fused into one instrument, with a common Kymographion. There are no valves in these spirometers, but the circulation of gases is ensured by means of motor-driven pumps. The flexible, double-lumen catheter used is of a new construction, devised by Carlens, our bronchoscopist. The lumen is wider than that of catheters previously in use. The catheter is introduced without the aid of fluoroscopy, and is provided with a small rubber hook that is automatically engaged by the carina. That this catheter permits the patient to breathe with very little resistance is amply proved by the fact that vital capacity is approximately the same with the catheter in situ as without it.

In judging the results of bronchospirometry, it is necessary to bear in mind that the right lung is larger and consequently has greater ventilation and oxygen consumption than the left. The ratio is approximately 53 to 47. It is interesting to note, in cases of unilateral disease, that oxygen uptake on the affected side is not necessarily directly proportional to vital capacity and ventilation in that lung. Oxygen uptake is often less than expected.

We consider oxygen the most important component to be determined, as carbon dioxide diffusion takes place much more easily, and is consistent in relation to ventilation. But Björkman and Carlens have recently shown—in investigations comparing oxygen consumption during exercise with a high oxygen content in the spirometers, and with atmospheric air—that the oxygen uptake of a diseased lung may be lower in atmospheric air than in oxygen. It is therefore probable that we must, in future, provide oxygen to maintain a stable composition of air in the spirometers.

Complications arising from bronchospirometry are rare and would appear to be almost completely avoidable, provided that the patient has little or no

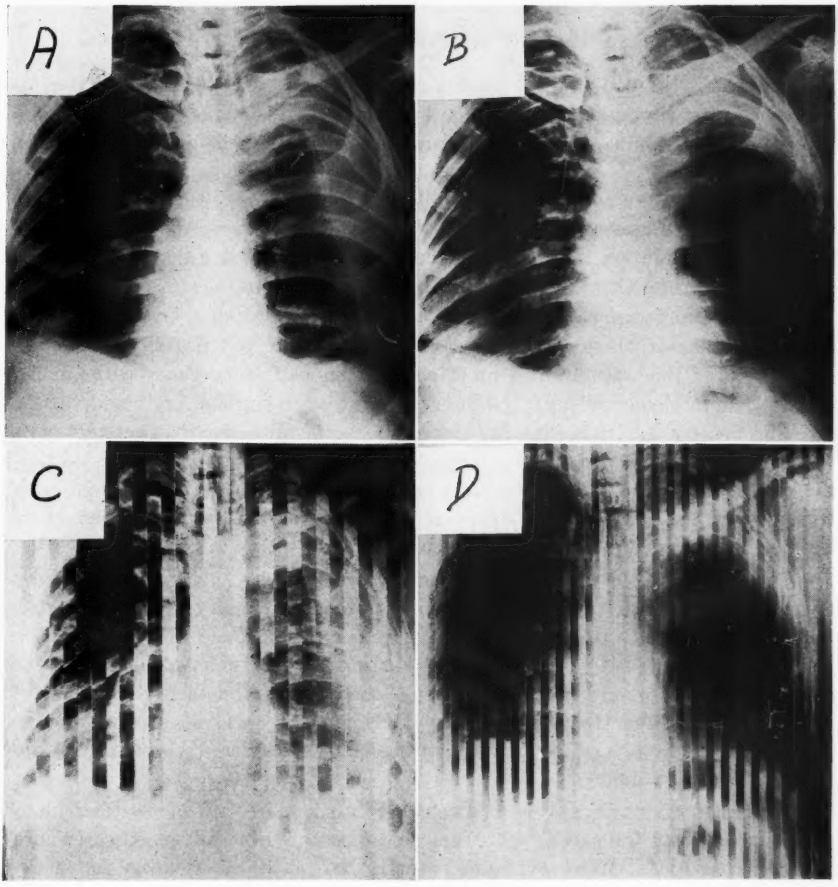

Fig. 4.—Ventilation insufficiency, improved after decortication.

E. K., a 41-year-old man, in 1943 was found to have bilateral apical infiltration with left cavity. Left artificial pneumothorax was attempted but was abandoned because of adhesions. Left extrapleural pneumothorax was performed in 1944. A severe postoperative hemorrhage caused reformation of the apical adhesions. By the end of 1945, further refills were impossible. The lung was encapsulated in grossly thickened pleura (*A*), and the patient was dyspneic in the extreme. Double exposure on maximal inspiration and expiration shows very limited movements of the diaphragm and chest wall (*C*). After preliminary P.A.S. medication, decortication of the left lung was performed in February, 1950, with great amelioration of subjective distress (*B*) and improved ventilation movements (*D*).

SPIROMETRIC INVESTIGATION

	NORMAL VALUES (calculated)	ACTUAL VALUES	
		BEFORE OPERATION	AFTER OPERATION
Absolute values (in liters, 37° C. saturated)			
equilibrium capacity	3.18	1.18	1.83
vital capacity	5.1	1.31	1.93
residual capacity	1.52	0.83	1.22
total capacity	6.62	2.14	3.15
Relative values (per cent of total capacity)			
equilibrium capacity	48.0	55.1	58.1
residual capacity	23.0	38.8	38.7
Maximum breathing capacity (liters per minute, 37° C. saturated)	120	38	56

BRONCHOSPIROMETRY

	BEFORE OPERATION					AFTER OPERATION				
	R	L	R+L	%R	%L	R	L	R+L	%R	%L
O_2 consumption per minute	0.285	0.033	0.318	89.6	10.4	0.244	0.081	0.325	75.1	24.9
Ventilation per minute	11.00	2.60	13.60	80.9	19.1	6.732	2.904	9.636	69.9	30.1

sputum and is in good general condition. The single case we have observed of acute spread of the tuberculous process to the basal parts of the lung was rapidly controlled by a course of combined para-aminosalicylic acid and streptomycin.

HEART CATHETERIZATION

The more pulmonary function is scientifically explored, the more obvious becomes its integration with the right heart. So intimate are the two that they seem to constitute a functional unit. In healthy persons, increased blood flow through the lungs appears to be ensured by the opening of a large number of reserve capillaries: these are closed in the resting state, but during exercise the active area of the vascular bed may increase ten to twenty times without significant rise in blood pressure. In diseases affecting the pulmonary blood-vessels, e.g., emphysema and tuberculosis, the area of the pulmonary vascular bed is reduced and the pressure in the minor circulation consequently increased. If the strain on the right heart becomes excessive, right cardiac insufficiency develops, with its characteristic dyspneic attacks, often in the almost complete absence of other symptoms of cardiac failure.

In order to avoid this right cardiac involvement, we have commenced preoperative registration of the pressure in the right pulmonary artery; catheterization is performed with the technique in common use. The fullest information seems to be obtained if some form of graded exercise is undertaken during the test so that the pressure reaction may be observed. This method is carried out by Hansson at Sabbatsbergs Hospital. It is too early as yet to estimate the significance of the procedure and to give normal values, but theoretically it appears to be most valuable.

Now that chemotherapy is so extensively used, more and more tuberculous patients come into the category of "arrested disease," even advanced cases with persistent cavities. Many of these patients have had tuberculosis for many years, and have greatly reduced pulmonary parenchyma. There is also considerable cardiac strain, and it may be difficult to decide if more may be added. In these patients, as well as in emphysematous subjects, the determination of the circulatory reaction during exercise must be of the utmost value.

SUMMARY

To obtain widened indications for pulmonary surgery in patients who, because of impaired function, would otherwise be deemed unfit for operation, pulmonary function should be evaluated by analysis.

The writers differentiate between: (1) *ventilation insufficiency,* which arises from bronchial anomalies or reduced costal and diaphragmatic mobility; (2) *parenchymatous insufficiency,* quantitative (loss of parenchyma), or qualitative (impaired diffusion of gases); (3) *insufficiency of the pulmonary circulation* (blockage or shunt).

The routine methods employed by the writers are: (a) *Radiological examination,* with registration of the movements of the diaphragm and thoracic cage. (b) *Spirometric investigation,* which includes the total lung volume and its

subdivisions and the maximal ventilation capacity. Special importance is attached to the relationship between the residual and total capacities and between the equilibrium and total capacities. Disparity in these relationships often heightens with increasing dyspnea. (c) *Bronchospirometry,* which is performed when other investigations show significant impairment of *total* lung function. (d) In certain cases, *catheterization of the pulmonary artery,* to determine the pressure at rest and during exercise.

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NOCARDIOSIS

Report of a Single Case With Recovery

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IN REVIEWING the literature, there are strikingly few cases of Nocardiosis reported, and the diagnosis in the great majority of cases was made either at autopsy or in the late stages of the illness. With the exception of a single case of Madura foot cured by amputation, only an occasional recovery has been reported, and those have occurred since the advent of sulfonamides.

Nocard[1] described an acid-fast sporothrix in 1888 as the cause of bovine farcy. In 1890, Eppinger[2] isolated an aerobic gram-positive acid-fast actinomyces from a fatal case of multiple brain abscesses and meningitis in man, describing this organism under the name *Cladothrix asteroides*. Since then the species of Actinomycetes having acid-fast properties have been described under various names. Finally the aerobic acid-fast Actinomycetales not forming condia were placed in the genus Nocardia. Many species of acid-fast Nocardia have been described, but in 1939 Umbreit[3] reduced these to the status of strains or variants of *Nocardia asteroides*. The genera Nocardia and Mycobacterium are closely related morphologically and culturally, but Drake and Henrici[4] concluded (1943) in their paper that the allergy induced against *N. asteroides* was specific, and that there were no cross reactions to tuberculin.

The first extensive review of the literature on this subject was in 1921, when Henrici and Gardner[5] collected twenty-six cases of acid-fast actinomyces, adding a single case of their own. The latter was a patient suffering from what appeared to be a pulmonary infection, who was treated with antigen, but the outcome was uncertain. Of the group of twenty-six cases there was only one recovery, and this was a patient with Madura foot who recovered following amputation. Since then single fatal cases have been reported by Goldsworthy[6] in 1937, and Kessel and Goolden[7] in 1938.

In 1944, Benbow, Smith, and Grimson[8] of this institution reviewed the literature and reported two new cases of *N. asteroides* with pulmonary and chest wall infections. Both of these patients were treated successfully with bed rest, surgical drainage, vitamins, sulfonamides, and iodides. These were the first patients known to have recovered, except for the previously mentioned patient with Madura foot.

In 1945, Binford and Lane[9] reported a fatal case, the diagnosis being made at autopsy. In 1946, Kirby and McNaught[10] added two fatal cases and also reviewed the literature, stating that of the thirty-two known cases of *N. aster-*

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oides, twenty-eight were dead at the time the report was made. Their two cases brought the total to thirty-four, only three of whom were known for certain to have survived, and one of the latter was the case of Madura foot.

In 1946, there were also reports of two single cases with recovery, one by Shaw, Holt, and Ray,[11] and the other by Calero.[12] The case reported by the former received penicillin, thymol, potassium iodide, sulfadiazine, and surgical drainage of an empyema cavity, while the case reported by Calero apparently received sulfonamides and penicillin in the course of treatment.

In 1948, Glover, Harrell, Heilman, and Pfuetze[13] reviewed the literature and added a case of a 26-year-old white male physician with an *N. asteroides* infection simulating pulmonary tuberculosis. Their patient was successfully treated with intensive sulfadiazine therapy, whereas penicillin and streptomycin failed to control the infection. The authors stated that from studies carried out in their laboratories and elsewhere, sulfadiazine appeared to be the drug of choice in the treatment of Nocardiosis.

In 1949, Hager, Migliaccio, and Young[14] reviewed the literature, and reported two additional cases. One was a 16-year-old schoolgirl with a pulmonary infection and empyema who was successfully treated by surgical drainage and combined therapy with sulfadiazine, penicillin, and streptomycin. The second case was that of a 64-year-old woman with bilateral apical pulmonary lesions. *N. asteroides* was isolated from the sputum, and by studies in vitro was found to be inhibited by penicillin, aureomycin, and streptomycin, but not by sulfadiazine in levels feasible to obtain clinically. There was no follow-up on this patient. They emphasized that it was necessary to observe patients carefully for several years for signs of recurrence.

Tucker and Hirsch[15] also reviewed the literature in 1949 and added three cases of their own, two of which terminated fatally. They mentioned that geographically the distribution of the aerobic type of Actinomycosis is world-wide, that there apparently is no occupational incidence, and that the disease appears to be fairly well distributed throughout adult life. They concluded that Nocardiosis should be considered in all patients with obscure or unusual chronic infections, especially when repeated attempts to demonstrate the tubercle bacillus have failed.

CASE HISTORY

CASE 1.—A. W., C-82777. This 37-year-old white tobacco farmer was referred to Duke Hospital on March 10, 1950, for investigation of a mass in the right lung field. One month prior to admission, because of fever, cough, and right anterior chest pain, he was admitted to his local hospital with a diagnosis of virus pneumonia. Roentgenogram of the chest showed a shadow in the right lung field. He was treated with penicillin without improvement or change in the roentgenogram picture, but it was stated that during his hospital stay he became afebrile. His cough was productive of approximately 2 tablespoonfuls of blood-streaked white mucoid sputum per day. There was an associaed 20 pound weight loss during the month in spite of a fair appetite. Because of persistence of symptoms he was transferred to Duke Hospital for further investigation.

The family history was of interest in that a sister had died thirteen years previously with pulmonary tuberculosis, and there was some question as to whether the patient's mother

had tuberculosis. The patient's general health had always been good, and his only recent illness had been a single attack of "malaria" in 1948. He had been obese all of his adult life, with his average weight being around 200 pounds and his weight at the time of admission being 180 pounds.

Physical Examination.—Temperature, 37° C.; pulse 80; respirations, 20; blood pressure, 148/100. The patient was a well-developed, obese, cooperative white man who did not appear ill. The examination was occasionally punctuated by a nonproductive cough. The skin was without lesions, and there was no lymphadenopathy demonstrable. Examination of the head, eyes, ears, nose, and throat was essentially normal. The trachea was in the midline, and there was no venous distention seen in the neck. The chest was barrel-shaped, but was symmetrical, and there was no respiratory lag. There was dullness to percussion in the right lower lung field anteriorly and posteriorly. Over this same area there were decreased breath sounds and diminished tactile fremitus. No râles were heard. The heart was not enlarged by percussion. The rhythm was regular, and there were no murmurs. The abdomen was protuberant, but there were no masses, tenderness, or rigidity. There was an easily reducible left inguinal hernia. The remainder of the physical examination, including rectal and neurological examinations, was essentially normal.

Accessory Clinical Findings.—Hemoglobin 15.3 Gm.; white blood cells, 20,000; platelets, adequate. Differential: segs. 76, stabs 5, juv. 4, eosinophiles 2, lymphocytes 13. Urine: pH 6.0. Specific gravity, 1.028. Protein and sugar, negative. Microscopic 0-1 white blood cell per high-powered field. No casts or bacteria. Posteroanterior stereoscopic and lateral films of the chest showed a density which seemed to be confined to the area of the right middle lobe (Figs. 1 and 2). Planigrams through this area revealed no cavities or discrete areas of calcification. Barium examination of the esophagus, stomach, and intestinal tract was normal. Cardiolipin test for syphilis was negative. Old tuberculin skin test, 1:1000 dilution, was 1 plus in 48 hours. Skin tests to blastomycin, coccidioidin, and histoplasmin were all negative. During the initial period in the hospital the patient brought up very little sputum, the latter being mucoid in nature and containing no blood. Routine cultures of the sputum grew *Neisseria sicca*, nonhemolytic *Micrococcus aureus*, a nonhemolytic Streptococcus, and *Streptococcus viridans*. Three concentrated sputum examinations were negative for acid-fast bacilli. Five separate sputum specimens cultured for tubercle bacilli were negative. One examination of the sputum for fungi was negative, and one culture for fungi was negative. On another occasion a routine culture of the sputum grew out an aerobic actinomyces, which was considered at the time to be a nonpathogen and a contaminant. Bronchoscopy revealed thick purulent secretions coming from the middle lobe orifice and narrowing of the middle and the lower lobe orifices by bronchitis. No definite tumor mass was seen. Specimens for Papanicolaou smears from the area revealed no tumor cells. Smears and cultures of the secretions for tubercle bacilli were negative. A routine culture of the secretions aspirated through the bronchoscope grew an aerobic actinomyces in eight days which was thought at the time to be a nonpathogenic contaminant.

Course in Hospital.—Throughout the fourteen-day period of observation and diagnostic survey the patient ran a low grade fever (37.5° to 38° C.) of the nonseptic type. He brought up little sputum until the fifth day after admission, at which time he was bronchoscoped. Following this, the amount of sputum increased to between 90 and 380 Gm. of mucopurulent sputum a day. During this preliminary period he was treated with intramuscular penicillin 300,000 units a day and penicillin aerosol 100,000 units three times a day. At the end of a two weeks' period no definite diagnosis could be made, so an exploratory thoracotomy was performed on March 23, 1950. At operation the pleural cavity was found to be completely free without fluid. There was complete consolidation of the entire middle lobe, and an area of involvement of the contiguous portion of the lower lobe measuring approximately 5 cm. in diameter. There was no involvement of the upper lobe. On dissecting in the major and minor fissures a thick, yellow, purulent material was encountered. It was the operator's impression that he was dealing with an inflammatory lesion rather than a neoplastic lesion, the etiology most likely being tuberculous. A right middle and lower lobectomy was then performed. The chest was closed leaving two drainage catheters in place after penicillin

and streptomycin had been instilled. Postoperatively he was treated with a total of one gram of streptomycin and 300,000 units of penicillin intramuscularly a day. An equivalent amount of the two drugs was placed in the chest each day. The postoperative course was complicated by collapse of the remaining right upper lobe, but with vigorous suctioning and coughing the lung re-expanded, and the course from then until the time of discharge on the eighteenth postoperative day was uneventful. The sections of the removed lung re-

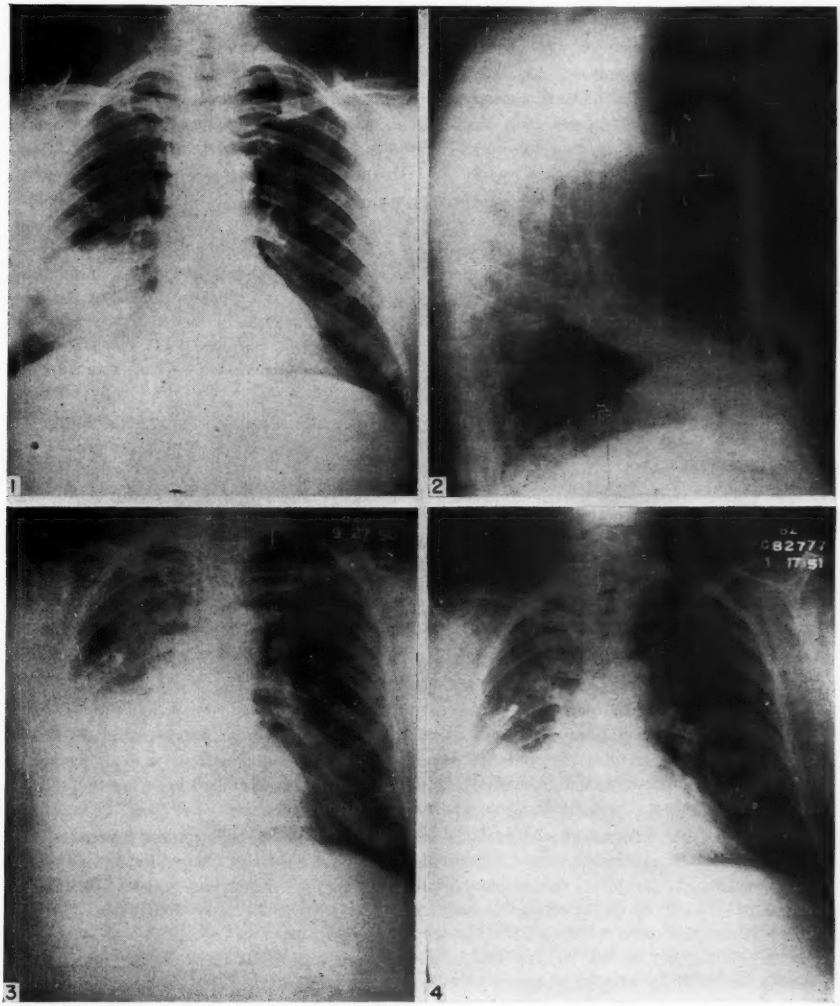

Fig. 1.—Posteroanterior roentgenogram of the chest taken on the day of patient's first admission to the hospital, March 10, 1950.

Fig. 2.—Lateral roentgenogram of the chest, March 10, 1950.

Fig. 3.—Posteroanterior roentgenogram of the chest four months after discharge from the hospital, Sept. 27, 1950. Residual lipiodol from injection of empyema cavity can be seen in the right chest.

Fig. 4.—Posteroanterior roentgenogram of the chest eight months after discharge from the hospital, Jan. 17, 1951.

vealed the middle lobe to be replaced by an indurated atelectatic parenchyma within which were noted multiple small foci of pale white areas containing a creamy-like material which grossly resembled caseation necrosis. Microscopic sections were characterized by a chronic inflammatory response consisting chiefly of lymphocytes and macrophages. In some regions the macrophages were loaded with fats. No characteristic granulomatous foci were encountered. *Gram stains* of the sections were not done. The lesion in the pathologist's opinion most closely resembled a chronic unresolved pneumonia in the nature of a lipoid pneumonia with multiple small abscess formations. The patient was discharged from the hospital on April 10, 1950, to be followed in the Out Patient Chest Clinic.

Second Admission: April 25, 1950. In the three-week interval during which the patient was home he did well until seventy-two hours before the second admission, when he developed an intermittent severe pain in the right chest and a cough productive of a small amount of white mucoid sputum accompanied by a mild headache and temperature elevation.

On admission the temperature was 40° C., respirations 35, pulse rate 100, blood pressure 140/90. He appeared acutely ill, and there was a slight cyanotic tinge to his lips. His skin was hot and moist. Examination of the eyes, ears, nose, and throat was as on the previous admission. The trachea was in the midline. There was a well-healed anteroposterior thoracotomy scar over the lateral aspect of the right chest. There was no redness or fluctuation in the operative scar. There was a dullness to percussion which changed to flatness from above to below over the right chest anteriorly and posteriorly. Breath sounds were absent over the right lower chest. There were a few râles at the right apex. The left chest was clear. Examination of the heart and abdomen was not remarkable. There was no calf or thigh tenderness, and the remainder of the physical examination was essentially normal.

Accessory Clinical Findings.—Hemoglobin, 10 Gm.; white blood cells 12,500. Differential: seg. 82, stabs 2, juv. 1, monocytes 3, lymphocytes 12. Urine showed no protein or sugar. Microscopic: 32 white blood cells per high-powered field, no casts or bacteria. Roentgenogram of the chest on the night of admission showed a haziness over the entire right lung field. Blood cultures revealed no growth.

During the first five days in the hospital the patient ran an extremely septic course, with temperature spikes to around 39.5° C. each day. This occurred in spite of two grams of aureomycin and 150,000 units of penicillin aerosol per day. Thoracenteses were done on several occasions without obtaining any fluid. On the fifth hospital day an abscess pocket was found in the sixth interspace posteriorly, and 15 c.c. of thick, purulent material were aspirated. On the following day the patient was taken to the operating room, and a large empyema cavity was drained. Because of the consistency of the purulent material, which was almost semisolid in nature, azochloramid irrigations to the empyema cavity were started. However, the patient continued to run a septic course with temperature elevation to above 39° C. each day for the next five days. Then the patient developed a draining sinus at the site of a previously made wound where an intercostal catheter had been located. This tract was further opened and a second empyema cavity drained.

The acid-fast cultures of the material aspirated from the posterior empyema cavity were negative. On routine culture the plate was again overrun by an aerobic actinomyces which was thought to be a contaminant, but in view of its abundance suspicions were aroused, particularly since material obtained from both of the empyema cavities at the time of drainage grew a pure culture of this fungus. Material from each of these empyema cavities was turned over to Dr. N. F. Conant of the Mycology Department who identified the organism as *Nocardia asteroides*. Several fresh preparations of the material were negative, but on Gram stain, gram-positive branching filaments could be identified. There were no other organisms obtained from either empyema cavity. Identification of the organism was made by the ninth hospital day, and the patient was started on 2 Gm. of sulfadiazine per day. Due to an error this was continued for five days, and had no effect on the patient's temperature. On the fourteenth day the mistake was discovered, and the dose was increased to 1 Gm. each of sulfamerazine and sulfadiazine every four hours, amounting to a total of 12

Gm. of sulfonamide per day. The urine was alkalinized with molar lactate solution and fluids were forced to 4000 c.c. per day. On the day following, the maximum temperature was 38.3° C., the first time since admission that it had not risen to 39° C. or above. Within four days the patient was afebrile. On this dosage of sulfonamide he gradually developed a microscopic hematuria, and the nonprotein nitrogen rose to 70 mg. per cent. For this reason the dosage of sulfonamide was cut in half, making a total of 3 Gm. each of sulfadiazine and sulfamerazine per day. Daily sulfonamide blood levels were done throughout the period of therapy, and the levels ranged from 17.5 to 25.2 mg. per cent, with an average around 20 mg. per cent. After reduction of the sulfonamide dosage the hematuria rapidly cleared, and the nonprotein nitrogen fell to normal limits. He was given several supportive blood transfusions. The drainage from the anterior empyema cavity rapidly ceased, and the drains were removed prior to discharge. The tube in the posterior cavity was withdrawn more slowly. During the last sixteen days of his hospital stay he was ambulatory and afebrile.

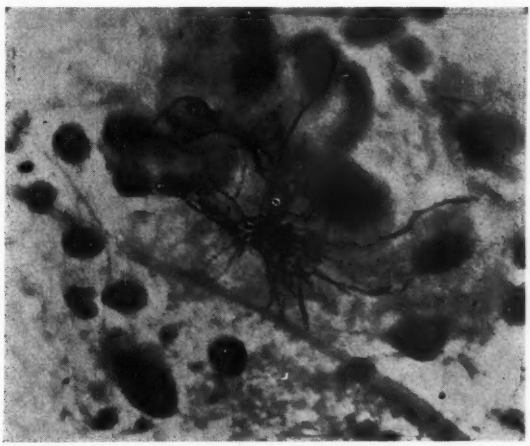

Fig. 5.—Gram-stained smear of the purulent material obtained from the empyema cavity at the time of surgical drainage. The gram-positive, delicate branching hyphae of *Nocardia asteroides* are readily seen.

He was discharged from the hospital on the twenty-sixth hospital day, May 28, 1950, to the care of his local doctor for biweekly changes of his surgical dressings, and biweekly hemoglobin, white blood cell, urine, and nonprotein nitrogen determinations. The same dosage of sulfonamide level was to be carried out for at least a three months' period of time.

Since discharge from the hospital the patient has been followed in the Surgical Out Patient Clinic at monthly intervals. Each time he has continued to show improvement. The posterior catheter was gradually removed during the month following discharge, and the wound promptly healed. A culture of the material from the sinus prior to its closure was negative for fungi. The nonprotein nitrogen and white count have been within normal limits on each occasion. The urine has shown no red cells. The sulfonamide level was 11 mg. per cent. The hemoglobin has ranged around 11 grams. The patient has gained in strength and weight. On Sept. 6, 1950, he developed a pain in the right lower quadrant with fever and elevation of his white count. He was taken to another hospital where under spinal anesthesia an appendectomy was performed. The operator stated that the appendix was acutely inflamed without evidence of chronic granulomatous process. The McBurney incision healed promptly without evidence of suppuration. Unfortunately the specimen was not saved.

The patient was kept on sulfonamide therapy from May 3, 1950, until Oct. 7, 1950, a total of five months of therapy. Since the discontinuation of drugs the patient has continued to do well and has had no complaints.

He was last seen in the Out Patient Clinic, April 12, 1951. The thoracotomy and empyema drainage incisions were well healed, and his chest film showed no evidence of activity of the old disease process (Figs. 3 and 4). He had gained approximately 80 pounds and had no complaints.

MYCOLOGY

Cultures of *Nocardia asteroides* were obtained from sputum, from secretions obtained by bronchoscopy, from lung tissue obtained at lobectomy, and from pus obtained from the posterior empyema cavity. The first isolations were thought to be contaminants because of the somewhat white chalky surface of the colonies and the slight earthy odor of the cultures which are characteristics of the aerobic soil actinomycetes, *Streptomyces sp.* When gram-stained and acid-fast stained smears of the material from the empyema cavity were examined, however, they revealed gram-positive and partially acid-fast, delicate, branching hyphae 1 micron in diameter (Fig. 5). Since such an appearance is characteristic of *Nocardia asteroides*, all cultures were re-examined and found to be consistent with this diagnosis.

Growth developed on blood agar plates at 37° C., in four to six days, as small, dry white chalky colonies with a slight earthy odor. On Sabouraud's glucose agar at room temperature (Fig. 6) the granular colonies produced an orange pigment with a thin powdery white surface. Microscopically, the culture was composed of long, delicate, branching hyphae 1 micron in diameter. When smears were made for Gram stains, the hyphae were seen to break up and appear as gram-positive bacillary elements. The fungus was also found to be partially acid-fast.

Two guinea pigs were inoculated intraperitoneally with heavy saline suspensions of colonies from Sabouraud's glucose agar slants and were sacrificed in two and three weeks, respectively. Few lesions were seen in these animals, and the organism could not be demonstrated by stained smears of various organs or peritoneal fluid. The organism was cultured, however, from a lesion in the liver of one of the guinea pigs. A third guinea pig was inoculated with a heavier suspension of the organism, and was found dead at the end of ten days. The peritoneum was studded with numerous, small, caseous nodules, and there were numerous enlarged mesenteric lymph nodes, which on sectioning were seen to contain yellowish white purulent material. Gram stained smears of the latter revealed *N. asteroides.*

PATHOLOGY

All of the sections of the involved lung were reviewed. There was a variety of inflammatory reactions, the most prominent of these being a chronic inflammatory response consisting chiefly of lymphocytes and macrophages. The overlying pleura was thickened, congested, and edematous, presenting the picture of an acute fibrinous pleurisy with many polymorphonuclear leucocytes in the subpleural connective tissues. Less conspicuous were areas of fibrosis in which there were giant cells and lymphocytes. Changes in the alveolar pattern of the lung varied from place to place, depending upon whether the predominant inflammatory response was acute or chronic. In the acutely involved area, the earliest changes seen were those of hyperemia and edema with a few polymorphonuclear leucocytes in the alveoli. The next change seen was that in which the alveoli were plugged with masses of polymorphonuclear leucocytes and small amounts of fibrin. If the process continued, the end result was the formation of numerous abscesses composed of polymorphonuclear leucocytes in all forms of preservation, fibrin, and tissue debris. Some of the abscesses communicated with bronchioles, and where this was seen the bronchiolar wall adjacent to the abscess was necrotic, the lumen being filled with polymorphonuclear leucocytes. In other areas the interlobular septae were thickened, and the alveoli were filled with edema fluid and contained many large foamy macrophages, lymphocytes, and polymorphonuclear leucocytes. Many of

the alveolar walls themselves were thickened and contained scattered lymphocytes. About the previously mentioned areas of abscess formation there was a limiting zone of dense fibrous tissue containing chronic inflammatory cells. Occasionally, evidence of an organizing pneumonia could be seen.

The offending organism could not be seen in ordinary hematoxylin and eosin preparations. Bacterial stains made on the tissue sections after the diagnosis had been established revealed the presence of delicate branching mycelia 1 micron in diameter which were gram-positive, but were not easily detected by the unexpectant eye (Fig. 7). Ziehl-Neelson stains revealed the organism to be weakly acid-fast with a tendency to take up the methylene blue counterstain in the tissue sections.

The pathologic findings differed from tuberculosis in that there were no epithelioid tubercles or caseation.

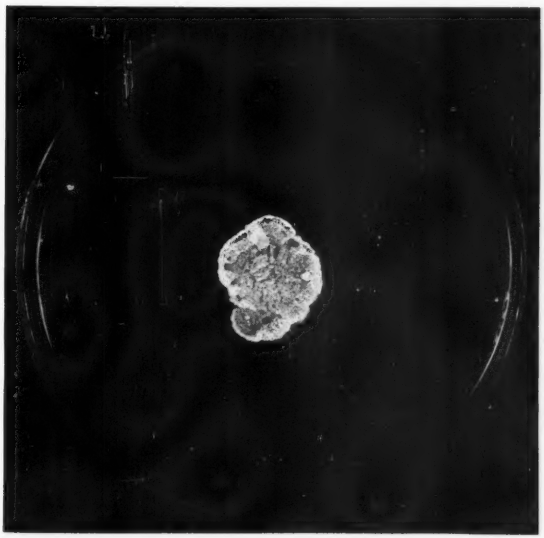

Fig. 6.—Culture of *Nocardia asteroides* grown on Sabouraud's glucose agar at room temperature for five weeks.

TREATMENT

As previously mentioned, of the reported cases of Nocardiosis definitely known to have survived, with the exception of the case of Madura foot, all received sulfonamide therapy in one form or another in conjunction with other forms of treatment. Hager and associates[14] reported a case of a 64-year-old woman with bilateral apical pulmonary lesions and a chronic productive cough. *N. asteroides* was isolated from the sputum as the predominating organism on several occasions. In vitro sensitivity tests revealed this particular strain to be inhibited by penicillin, aureomycin, and streptomycin, but not by sulfadiazine. Apparently no further tests were made with other sulfonamides. There is no follow-up on this patient, and it is merely stated that she was afebrile during a short period of observation.

Strauss and associates,[16] in their report on the chemotherapy of Actinomycosis and Nocardiosis, did in vitro studies on ten different strains of *Nocardia asteroides* with fourteen chemotherapeutic agents. The greatest inhibition was seen with aureomycin, chloramphenicol, terramycin, Myvizone, and N,N-bis (thiocarbamyl) hydrazine. Sodium sulfadiazine was only moderately effective in vitro against all of the strains tested. On the other hand, when animal protection tests were used, sodium sulfadiazine afforded almost 100 per cent protection, while the above-mentioned chemotherapeutic agents gave only partial protection.

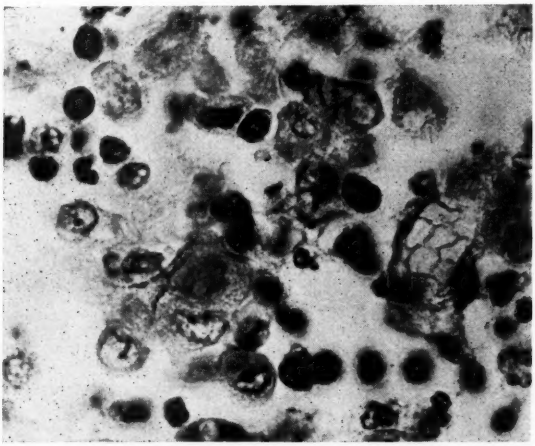

Fig. 7.—Gram stain of a tissue section from the involved lung. Short gram-positive hyphae can be seen.

In our case in vitro sensitivity tests were not done. Following large doses of sulfonamides the patient became afebrile in four days. Sulfadiazine and sulfamerazine were used jointly rather than one or the other in hopes of lessening the chance of renal complications in view of the large dosage of sulfonamides deemed adequate for treatment. We strove to maintain blood levels ranging around 20 mg. per cent while the patient was in the hospital and felt that it was quite important that the patient be kept on sulfonamide therapy for several months. Needless to say, patients under this vigorous regimen of sulfonamide therapy must be watched closely for renal complications and leucopenia.

During this patient's hospitalization he received large doses of parenteral penicillin, aerosol penicillin, and streptomycin and aureomycin at one time or another, none of which had a specific effect on the temperature curve. He also received accessory vitamins and iron. Surgical drainage undoubtedly was an essential part of his treatment.

Of the forty-two cases of Nocardiosis reported in the literature through 1949, excluding the case of Madura foot, only seven can be considered clear-cut

examples of recovery. This is the third case to have recovered at this institution,[8] and brings the total to eight recoveries of forty-three reported cases.

CONCLUSIONS

1. The literature is reviewed. There are strikingly few cases of Nocardiosis reported. This is most likely due to failure of recognition of many cases.

2. The case of a 37-year-old white man who was explored for a possible pulmonary neoplasm and subsequently found to have Nocardiosis is reported. The patient survived following drainage of an empyema cavity and intensive sulfonamide therapy, and is living and well one year later.

3. Nocardiosis is caused by *Nocardia asteroides*, an aerobic, gram-positive, partially acid-fast actinomyces. The mycology of this case is discussed.

4. Pathologically one sees both an acute and chronic inflammatory reaction which differs from tuberculosis by the absence of epithelioid tubercles and caseation.

5. Of forty-three cases of Nocardiosis reported in the literature (including this case) only eight can be considered clear-cut examples of recovery. Three of the latter have been reported from this institution. Of those recovering all received sulfonamide therapy in one form or another. It is essential that these patients receive adequate dosage of sulfonamides and apparently be maintained on therapy for four to six months.

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PULMONARY RESECTION FOR HISTOPLASMOSIS

A Case Report

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GREAT interest has been manifested in histoplasmosis in recent years. The discovery of a useful skin test for this infection has revealed its widespread prevalence in the lower Mississippi Valley Basin. The vast majority of persons with a positive skin test are apparently normal with only some pulmonary calcifications remaining as evidence of the obsolete infection. At the other extreme there have been described a small number of highly fatal cases of disseminated histoplasma infection. Between these two extremes there have been noted a small number of patients, usually children, with early infiltrations due to histoplasma. These have usually cleared without evidence of serious illness. The case to be described below does not fit into any of the above categories. It is, therefore, felt to be of interest, particularly since it may easily be confused with pulmonary tuberculosis. This is also one of the earliest diagnosed cases to be treated by pulmonary resection. No review of the literature will be given here since this has been adequately covered in recent publications.[1]

CASE REPORT

Mrs. M. T., born in 1914, had resided most of her life on farms in Ohio and Illinois. Her past history was noncontributory. The present illness apparently began in April, 1948, with a sore throat which persisted for about two months. This was followed by rhinitis and sinusitis for two weeks. These subsided and were promptly followed by evidence of lower respiratory infection with cough. In July, 1948, she improved but continued to feel fatigued. By September the fatigue increased, she had more cough, and complained of pain in the chest. There was very little sputum, no hemoptysis, no night sweats. Her private physician referred her to the Livingston County Tuberculosis Sanitarium. Physical examination (Oct. 11, 1948) was essentially normal, except for fever to 100° F. She was ambulatory and did not appear acutely ill. No definitely abnormal findings were noted in the examination of the chest. Roentgenograms on admission showed abnormal densities above the right interlobar fissure and lateral portions of the right lung, extending upward to the clavicular level. There was some rarification noted suggestive of a motheaten type of cavitation. Mantoux tests with tuberculin PPD first strength and second strength were negative. Repeated search of the sputum for tubercle bacilli was negative. Gastric lavage specimen was negative for tubercle bacilli on culture and guinea pig inoculation. Sedimentation rate was 26 mm. Weight was 115 pounds. Blood count was within normal limits. Undulant fever and Kahn test were negative. The patient remained in the sanitarium until Jan. 24, 1949, with considerable symptomatic improvement. She became afebrile and gained weight to 134 pounds. Films of the chest, however, revealed only slight improvement. Study of the patient was continued in the outpatient clinic. A skin test was done with histoplasmin 1:1000 and found positive. Sputum specimens were examined for histoplasma capsulatum by the Illinois Department of Public Health and found to be positive on the following dates: Feb. 15, 1949, Feb. 24, 1949,

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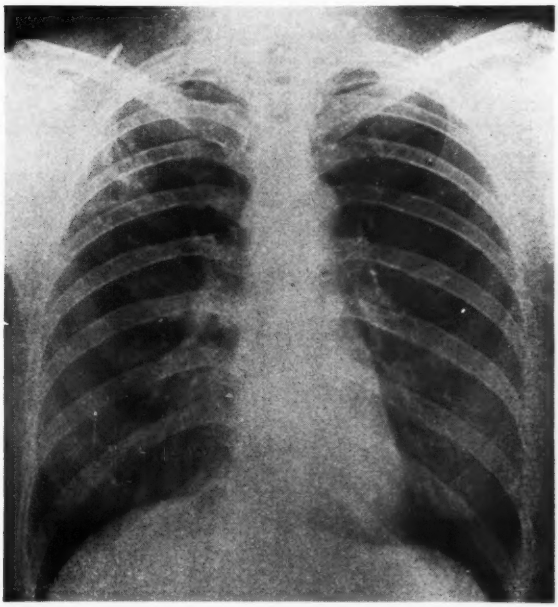

Fig. 1.—Infiltration in right upper lobe, Nov. 13, 1948.

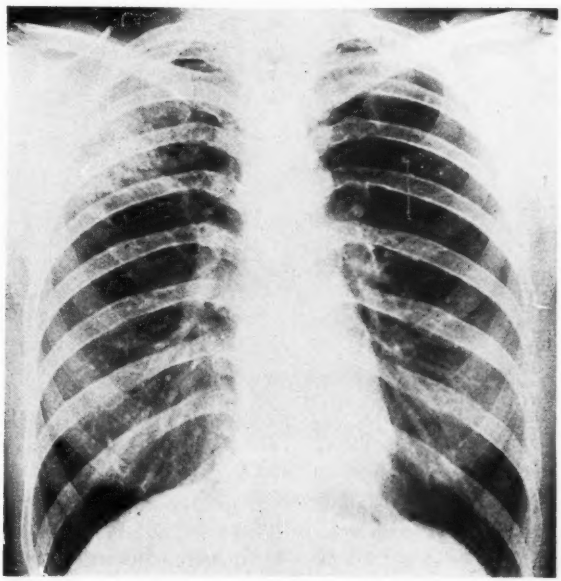

Fig. 2.—Cavitation in the right upper lobe, May 2, 1949, prior to resection.

April 27, 1949, and Sept. 1, 1949. Blood was examined for complement fixing antibodies by Dr. Michael L. Furcolow of the U. S. Public Health Service. This test was positive for histoplasmosis on March 30, 1949, April 19, 1949, May 1, 1949, August 8, 1949, and April 28, 1950. In November, 1950 the test was negative.

During her stay in the sanitarium the patient was treated with a course of penicillin daily for about one month. Streptomycin 1 Gm. daily was given from February, 1949, to April, 1949. In May, 1949, the patient was given aureomycin therapy 2 Gm. daily for about three weeks. Treatment had slight, if any, effect on the roentgenogram appearance of the lesion. Because of this, pulmonary resection was recommended. In February, 1950, a wedge resection of the lesion was done* at the Mayo Clinic with uneventful recovery. Follow-up of the patient to the present time (March, 1951) reveals no evidence of recurrence.

Description of specimen: The lesion measured 6 by 4.5 by 3 cm., and showed cavitation. Histoplasma capsulatum was cultured from the removed specimen. Histologically it was diagnosed chronic granuloma with cavitation.

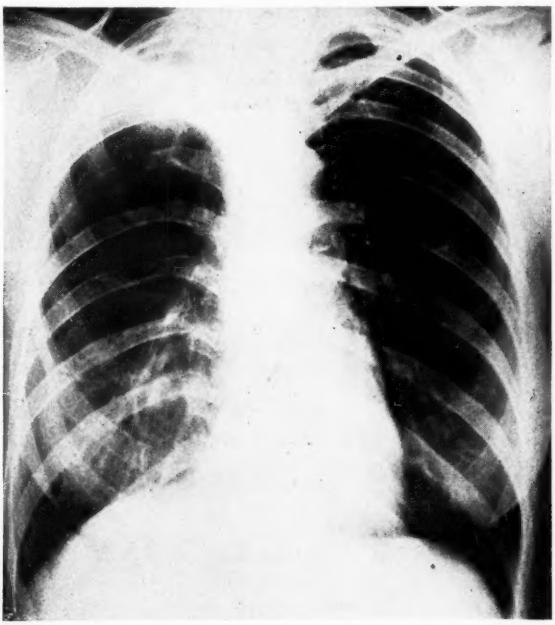

Fig. 3.—Roentgenogram Oct. 27, 1950, following resection.

DISCUSSION

It has become obvious that infection with histoplasma capsulatum may have several different manifestations. The commonest of these is the presence of a positive skin reaction to histoplasmin. Varying percentages are found east of the Rockies, reaching a peak of 80 per cent of persons living in the vicinity of Kansas City. A large proportion of these persons show multiple pulmonary calcifications, frequently larger in size than those associated with primary tuberculous lesions. A careful search for the stage of the disease

*By Dr. O. Theron Clagett.

which precedes these calcifications has revealed that it takes the form of small pulmonary infiltrations, frequently subclavicular, and usually without clinical symptoms. These infiltrates have usually been found in children, although it is probable that they occur in adults also, but are frequently overlooked. Another form of the disease consists of that in which there is dissemination to numerous

Fig. 4.—Photograph of gross specimen, resected February, 1950.

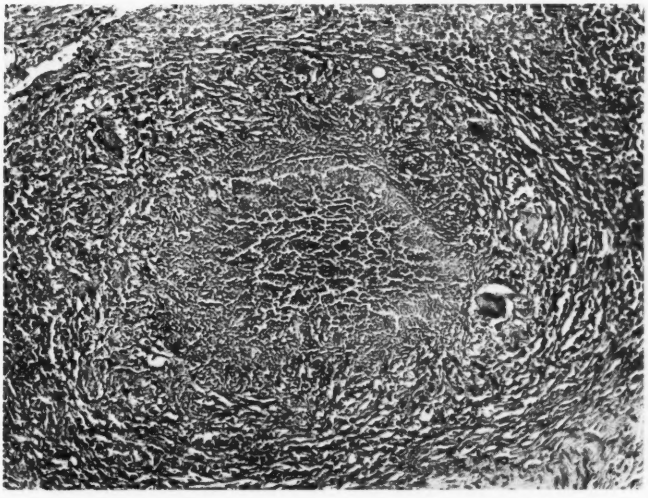

Fig. 5.—Photomicrograph of the lesion, showing granuloma with giant cells.

organs. In this form, the skin test is frequently negative and the outcome usually fatal. The diagnosis is usually made at autopsy. A fourth type of this disease is the destructive but localized type of pulmonary lesion seen in this patient. This has rarely been described, and is easily mistaken for pulmonary tuberculosis.

It appears then that the life cycle of histoplasma capsulatum infection resembles that of pulmonary tuberculosis very closely. It begins with pulmonary infiltrations which are asymptomatic, frequently healing with calcifications, thus resembling primary tuberculosis. Reinfections later in life may take the form of isolated organ histoplasmosis such as the pulmonary lesion described in this paper or the disseminated and highly fatal form, thus again resembling some of the adult type of tuberculosis.

The diagnosis in this patient was aided by the fact that the patient had a negative tuberculin test. It was proved by the presence of a positive histoplasmin test, the repeated finding of histoplasma capsulatum in the sputum and the presence of the complement fixation reaction in the blood serum. It was verified by culture of the organisms from the surgical specimen.

Drug therapy was unavailing, and up to the present time no drug has been described which has any marked effect upon this organism. This renders the treatment by means of resection the only therapy at our command at present.

This case accents the importance of making a careful diagnosis in patients who have lesions resembling pulmonary tuberculosis. Any patient who has a negative tuberculin test must be presumed to be nontuberculous. Failure to find tubercle bacilli after adequate search should be a warning to look thoroughly for other disease.

CONCLUSION

A case of a rarely described type of histoplasmosis, diagnosed prior to surgery, is presented. This was a destructive isolated pulmonary lesion apparently cured by pulmonary resection. The diagnosis was proved by the histoplasmin skin test, the presence of histoplasma capsulatum in the sputum repeatedly, and the finding of positive complement fixation reactions in the serum. The organism was also found in cultures from the surgical specimen. This is believed to be one of the earliest cases to be diagnosed prior to planned surgical resection.

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REFERENCE

1. Pratt, P. T., Schwartz, S. O., and Ehrlich, L.: Aspiration Biopsy of Bone Marrow as an Aid in the Diagnosis of Histoplasmosis, Arch. Int. Med. **85**: 893, 1950.